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Physical Review, June, 1924

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLIII AUGUST, 1924 Number 8

Scenic Wonders on Pasadena Trip

An enjoyable way of seeing some of the most wonderful scenery of the West is being offered in the special trip which will be made from the East in connection with the Fall Convention of the Institute at Pasadena, October 13-17. A special train or special cars will carry a large group of Institute members, making stops at a number of places of interest. The round trip will require about one month, starting late in September. Special rates will be available. Although the plans for the trip have only recently been formulated a large number of prominent members is already on the list of those who intend to take the journey, and the list is growing daily.

A most delightful feature of the trip will be that a number of the noted pioneers of the Institute, utility executives and prominent engineers will be present in the party.

In the West there will be opportunities to meet the Western men of the electrical industry and to learn about the methods and developments of that section.

At the Convention there will be addresses by the pioneer members and also by a number of prominent executives.

Transmission engineers will be particularly fortunate in taking this trip as they can study the latest practises on the Coast and also because three sessions at the meeting will disclose the most advanced studies on this subject of transmission. More details are given elsewhere in this issue on the program of the Convention.

Suggestions to Authors

The Institute has published for many years past a small pamphlet under the above caption, which was designed to aid prospective authors in the preparation of Institute papers, JOURNAL contributions, revision of discussion, etc. Recently a revision of this pamphlet has been undertaken and a new edition, is now nearly completed and will be available for distribution this month. Quoting from the Introduction the pamphlet states:

"Papers submitted should be in accordance with Institute requirements and this booklet is published for the purpose of supplying to the membership, in condensed form, the requirement of the by-laws, and of the Meetings and Papers, and Publication Committees, relating to the scope and form of acceptable papers.

"This revised edition, it is believed, will provide authors with many time-saving and otherwise helpful suggestions; and will also assist the committees in controlling to better advantage the heavy expenses of publication which have become a serious factor in the management of the Institute.

"Any member desiring to present a paper at an Institute meeting should give early notice to the Meetings and Papers Committee and to the Chairman of the proper Technical Committee, as programs must necessarily be arranged several months in advance. In order to allow time for a careful preparation of discussion, every effort is made to publish papers in pamphlet form, or in the monthly JOURNAL, prior to the meetings at which they are presented.

"Although these suggestions are intended primarily for those who prepare papers for Institute meetings, they will prove equally helpful in preparation of papers for Section meetings and for publication in the monthly JOURNAL of the Institute."

Prospective authors and others interested are urged to avail themselves of the help afforded by this pamphlet which is sent free of charge on request, and which contains suggestions which may avoid unnecessary delay and correspondence in the handling of Institute papers.

A Need for Biographies

A leading editorial recently appeared in a New York daily newspaper calling attention to the notable dearth of biographies of modern American men of Science. The writer of the editorial pointed out that frequently our foremost engineers acquire world honors in scientific circles and, while well known among their fellows, are almost entirely unknown to the public at large in our own country.

There is an explanation of this situation which fits in with the conditions surrounding progress and development in a "comparatively new country," but it is well to realize that Science, as we know it today, is about as old in America, as in any other country.

A long period of non-war existence, which we hope is ahead of us, fosters industrial progress along competitive lines to an extent which tends to make personal advancement, a matter of achievement. Ambition is surely on a sound basis when the oncoming generation

of engineers has a means of studying the characters, methods and accomplishments of their seniors in the profession.

Systems of engineering education might well include studies of the professional history of eminent engineers and inventors.

Publishers of books might possibly hasten the day when engineering biography shall be widely available, by trying out a well thought out scheme of publication —it is a publishing problem, but the elements are not particularly difficult of identification.

Some Leaders of the A. I. E. E.

William Arnold Anthony, sixth president of the Institute, was born in Coventry, R. I. in 1835. He graduated at the Sheffield Scientific School, Yale University, in 1857, and became professor of physics at the Iowa Agricultural College, later going to Cornell University, where he founded the first college course in electrical engineering.

In 1887 Prof. Anthony went into business for himself as a consulting engineer and in 1895 joined the faculty of Cooper Union as professor of physics and electrical engineering, where he remained until his retirement in 1908.

Besides being one of the pioneer members of the Institute, he was also associated with the Franklin Institute of Philadelphia, the American Social Science Association and the Brooklyn Institute of Arts and Sciences.

Although he was a man of a very retiring nature, the splendid work he did has had far-reaching influence. He was the author of several books and made a number of contributions to the A. I. E. E. and to engineering publications.

His death in the year 1908 was a great less to the Institute and to the engineering profession in general.

The Station Load

Commercial electrical engineers, throughout the Country, whose task it is to develop increased station loads, have been ingenious and successful in uncovering new ways in which electricity may be used to the advantage of industry. The field has been so combed that at times it seems to individual solicitors that there is not a remote excuse for one more electric motor in the town.

This situation suggests that something may perhaps be accomplished by employing more extensively the methods used successfully by the railroads in developing traffic for their lines.

It is rarely that every town, or every establishment in every town, has all of the modern facilities that it might profitably have. The successful salesman of electric power, if he allows his imagination free rein, can uncover weak spots in many mercantile and industrial plants which would be strengthened by the installation of systems and devices in these instances not at present utilized.

In this connection many utilities come to mind—such as refrigeration, ventilation, heating, air compressors, motor-blower operated pneumatic tube systems for transferring papers, elevator operation, et cetera. Pointing out to plant managements, office managers and executives the savings effected by the use of every modern facility, furthers the prospects for the sale of electric current.

The pathway of the salesman of labor-saving devices is being cleared of obstacles.

The station load increases as the use of electricity is extended to replace slower and more expensive means of carrying on necessary operations.

B. G. Lamme's Will Aids Engineering Students

After providing bequests to the members of his family, the will of the late Benjamin G. Lamme, notice of whose death appears elsewhere in this issue, makes provision for a number of engineering scholarships and awards to take care of students, technical teachers and engineers along certain electrical and mechanical engineering lines.

Two scholarships are established by the will for the two most capable students in mechanical and electrical engineering courses at the Ohio State University, Columbus, Ohio, Lamme's Alma Mater, during their senior year. A trust fund of $15,000 has been set aside for this purpose.

A fund of $6000 has been set aside for a gold medal to be awarded annually to graduates of one of the technical departments of Ohio State University for meritorious achievements in engineering or technical arts. Two medals may be awarded during a period of one year if the accumulated interest warrants it.

Provision has also been made for the Society for the Promotion of Engineering Education or some other suitable organization which shall give a gold medal yearly to the chosen technical teacher for accomplishment in technical teaching or actual advancement in the art of technical teaching. A trust fund of $6000 has been established for this purpose. If the accumulated interest warrants, two medals may be awarded in one year.

The will also provides a trust fund for which $6000 has been set aside for the American Institute of Electrical Engineers for a gold medal to be awarded annually to a member of that society for meritorious achievement in the development of electrical apparatus or machinery. If the interest from the fund permits, two medals may also be awarded during a period of one year.

The splendid collection of Indian relics which Mr. Lamme had collected during his life time is given to the Ohio State University.

The Development of a Suspension-Type Insulator

BY HAROLD B. SMITH
Fellow, A. I. E. E.
Prof. Elec. Eng., Worcester Polytechnic Institute, Worcester, Mass.

Review of the Subject.—*Increasing voltages employed in transmitting large amounts of power over long distances emphasize the need of a better line insulator for this purpose. This paper outlines the conditions under which a suspension-type insulator has been experimentally developed for such use. In the form described, it consists of metallic terminal members to suitably distribute the electric flux and an insulating, impregnated wood (or other material) mechanical strain member, concentric with the hollow electric field produced between the metallic terminal members. The unit described is designed for use on 110,000-volt power lines, two similar units in series for 220,000-volt lines and, when necessary, three units in series on 330,000-volt lines. The fundamental principles of the insulator are established and later continued experience in service may or may not modify detail.*

Introductory

One of the important problems involved in long-distance high-voltage power transmission at the present time is that of the line insulator. For the last 30 years, constantly increasing voltages have been employed for power transmission and each increase in line voltage has brought its problems of design of the several component parts, which together constitute such a system; transformers, bushings, line conductor for corona losses, regulation, control, etc.; insulation, insulators, etc.

Step by step the work of investigation, development, and resulting design of the several parts of high-voltage systems has kept pace with the commercial and economic demands for ever increasing line voltages. Some of the time, possibly, one or more of these factors has lagged behind the development demanded by the situation, but, in general, the engineering investigation and design of the various features have kept pace with and, in certain instances, have clearly pointed out a path of accomplishment in advance of economic needs.

Fig. 1 indicates what this advance in line voltage has been through the years. Voltage values for line insulators, bushings and power transformers, as distinguished from testing transformers, have followed a similar advance. Testing transformers and their bushings have ranged at from four to six times the voltage of the power transformer or line voltage for a given period.

We have been confronted, from time to time, in this progress by what appeared, at the time, to be insurmountable difficulties. First the transformer could not be insulated, then, when it was insulated, the higher voltage could not be brought out through any available bushing. When this was accomplished, and the higher voltage was applied to the line, the known insulators failed and the line could not be insulated. After securing a line insulated from earth with improved insulators, the atmospheric and corona line losses were found to be such that the possible limit for line voltage was at one time set at 60,000 volts. Within three years of that time, it was shown that 60,000 volts was not the limit and within six years, the law of design for corona line losses was established. Recently we have had limits set for the amount of power which can be transmitted over long distances.

As frequently as some apparently impossible barrier has presented itself, it has been surmounted and this has gone on, time after time, through the efforts of many engineers and scientists, until the earlier and, at the time, really difficult barriers to surmount, now look as simple from our present point of view as our present

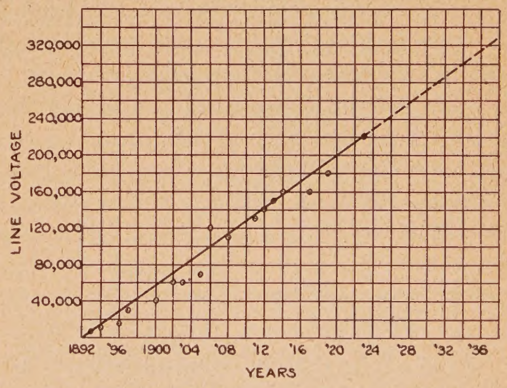


Fig. 1

"impossibilities" are likely to appear a quarter of a century from now.

The advance in power transmission line voltages, from the beginning of its advance over thirty years ago to the present time, has been consistent and uniform. It, at least, suggests the possibility of a continuance of a similar rate for some years to come. Whether we reach 300,000 or 350,000 volts for superpower transmission line potentials before or after 1935 or 1940 is perhaps not important. However, the case does appear to be clear that we are to advance in this direction, and that the times and the values for such line voltage increase are to be set, mainly, by economic rather than by purely engineering limitations.

These considerations, together with stimulation from

Presented at the A. I. E. E. Regional Meeting, Worcester, Mass., June 4-5, 1924, and to be presented at the Pacific Coast Convention, Pasadena, Cal. Oct. 13-17, 1924.

work on other related factors of this problem, led the writer, early in 1920, to apply himself to the definite problem of the rational design of an insulator which might be better adapted to increasing line voltages than those then available. This paper will present the results thus far secured on that portion of the problem which relates particularly to the suspension type of high-voltage line insulator. Parallel work has been carried out on the application of these principles to the design of pin type insulators and to transformer and bushing design, but an account of this work will not be attempted within the limits of this paper.

In order to show the relationships of this problem, it may be well to outline most briefly the gradual development of the high-voltage line insulator. The first telegraph lines required insulators and, starting with the early split tube insulator of Ezra Cornell as an illustration, we have a duct with the insulating material (glass, pottery or porcelain) placed in compression. The development of the insulator, until most recently, has been along purely empirical lines upon this original basis of a capped duct or tube with the insulating material in compression. A fairly standardized glass, pottery or porcelain insulator for telegraph and telephone service yielded many years of satisfactory experience before there was need of insulators for the early light and power circuits. These early light and power circuits did not range above 700 volts, except certain series arc and incandescent systems which ranged up to 5000 or, in some cases, as high as 10,000 volts.

When 5000 volts or more were applied on the line, although below corona effects, difficulties were experienced and merely making a large capped duct or tube type telegraph insulator did not entirely answer the question. However, this type was still adhered to, and by making modifications of an empirical character, improved materials, petticoats, etc., improved puncture and leakage loss values, creepage surface, hygroscopic conditions, etc., etc., an insulator resulted which served its purpose for the higher voltages.

With the advent of corona forming voltages, there opened a new chapter of insulator development, in which much of the earlier experience was no longer applicable and a number of new theories and resulting designs appeared. These principles at first neglected the direct question of the surrounding electric field and were applied empirically to the preceding type of insulator,—still a capped duct with the line and tie wire at or near the top of pin and the insulating material still in compression. Corrugated surfaces, multiple parts, multiple petticoats, improved dielectric strength of materials, creepage current distribution, leakage losses, etc., etc., produced insulators which again served their purpose, although usually of faulty design and often concentrating electric flux unnecessarily so as to lower breakdown values they might otherwise have possessed.

A more careful study of this problem next led to a departure from the continued empirical development of the original tube or duct type and the rational application of theory to insulator design as based upon the study of dielectrics in air and the electric field of the insulator and its surroundings. The theory was stated by Maxwell many years ago, but its application to the improvement of insulator design was then new and is now firmly established in its application. The fact, then appreciated, that a conformity of the contour of the surface of the insulator to the electrostatic lines of force of the electric field gives a closer practical approach to the dielectric strength of surrounding air than can be secured by any other surface, was applied in the production of a new type of insulator. This insulator had introduced a new element into this class of design and, because the lines of mechanical stress were parallel to the electrostatic flow lines, an insulator was produced in which the material (porcelain) could be used otherwise than in simple compression and need be no longer of the simple tube or duct type. It was no longer necessary for the line and tie wire to surround or approximately surround the top of the pin. The resulting insulator introduced these principles together with surfaces of rain sheds conforming to equipotential surfaces of the surrounding electric field.

With further increase in line potentials above 100,000 volts, even this development of the pin type insulator no longer met the demands and, even before this latter development, suspended strings of insulating (porcelain) units came into high-voltage line practise. This was another departure from the earlier empirical duct or tube type and appeared, at first, to take care of the difficulties imposed by steadily mounting line voltages. However, it was soon found that a string of such units, because of capacity relations, would not withstand a voltage equal to the sum of voltages which could be applied to the individual units. This effect, together with increasing costs and lengths of such strings of units for the higher voltages now in use or contemplated in the near future, leaves much to be desired and possibly presents another barrier.

Statement of the Problem

In former insulator designs, and until the application of the flow-line principle and the use of the string of suspension units, it has been the practise to design for higher and higher voltages by increasing the dimensions, improving the materials, multiplying the parts, etc., as based empirically upon previous experience with the tube or duct type insulator and its modifications. Even with the application of the flow-line principle to commercial designs, the surfaces of the porcelain were shaped to conform to the lines of force of a field resulting from previous practise as to location and shape of metallic terminals.

In all of these designs, the porcelain insulating surfaces, or some of them, were in the path of maximum potential gradient and along the path by which corona formation and final breakdown and arcing would occur.

In order to proceed effectively to the design of insulators for higher voltages, it appeared advisable to introduce certain elements and principles not heretofore employed and looking toward:—

(1) Placing the insulating surface under more favorable conditions for operation, especially as to corona and arcing.

(2) Simplifying the form of the insulating surface for convenience in manufacture.

(3) An insulator free from corona prior to breakdown.

(4) Reducing weight.

(5) Reducing over-all length.

(6) Reducing costs.

(7) Producing a higher voltage unit insulator.

(8) Elimination of porcelain, if possible.

These results may be attempted by the application, among others, of the following features:—

(9) The production of a hollow electric field[1], in which to place the insulating member.

(10) In combination with the hollow electric field, to so shape metallic electric flux distributing terminals as to produce along and near the axis of the field a field of force with lines so distributed as to conform to the surface of an insulating (mechanical strain) member which shall be most desirable from purely mechanical considerations of strength and manufacture.

(11) In combination with the above, to so proportion the metallic flux distributing terminal members as to eliminate corona formation anywhere on the insulator prior to a close approach to breakdown voltage, and well above operating voltage.

(12) An insulating mechanical strain member, to meet the purely mechanical conditions imposed by a higher voltage line insulator and, conveniently manufactured, may be an elongated cylinder or frustum of a cone or close approach to such forms.

(13) A mechanical strain member employed in the above combination should either be of some material of better mechanical properties than porcelain or of a porcelain having mechanical properties superior to those heretofore employed in insulator construction.

A proper combination of the above features should result in an insulator which will offer, among other advantages:—

(14) No possibility of corona or arcing along its single insulating surface; opening the possibility of the use of other material than porcelain.

(15) Maximum practicable dielectric strength along its insulating surface.

(16) Ample mechanical strength.

(17) A single unit suitable for use on 110,000-volt power lines, two such units in series for 220,000-volt lines and, when necessary, three units in series on 330,000-volt lines.

1. By a hollow electric field is meant an electric field surrounded symmetrically along its axis (plane or other surface) by a stronger field of higher average and maximum potential gradient.

Experimental Development

The preliminary experimental work of development

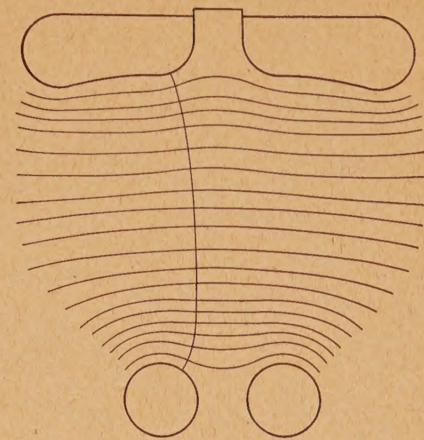


Fig. 2

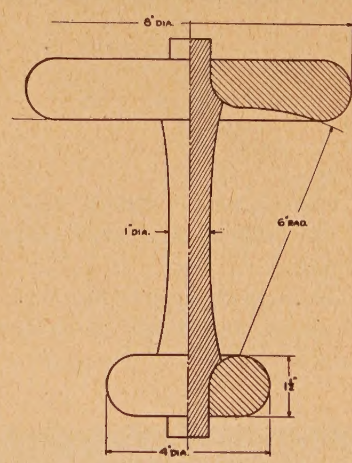


Fig. 3

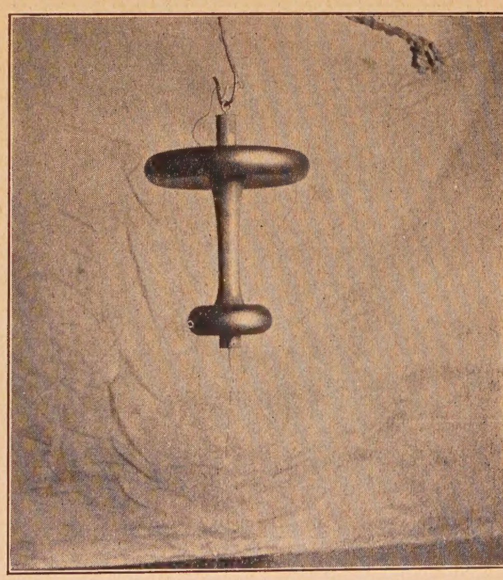


Fig. 4

of an insulator to meet the above conditions has now been completed and a few preliminary commercial

model suspension insulators have been built to place on high-voltage power circuits. This will give service experience with a view to detail modification, if necessary, before placing such insulators in general service in quantity.

The results obtained in this experimental development are of interest and, without attempting a full account of all the experimental work involved, may be outlined as follows:—

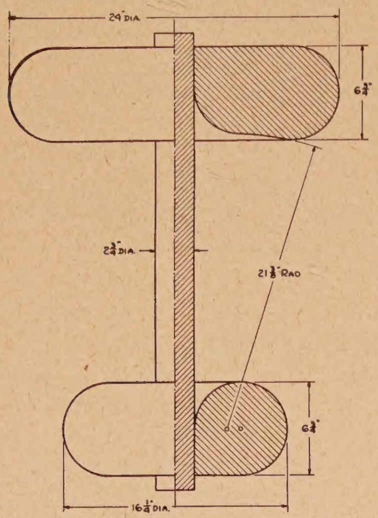


Fig. 5

An early attempt to determine, by theoretical analysis, a suitable form of insulating surface resulted in a form of spindle shown in Fig. 2 and dimensions as in Fig. 3.

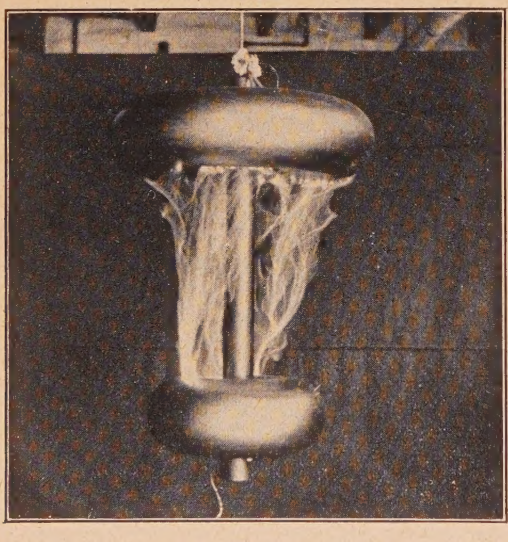


Fig. 6

This was constructed of wood with gilded terminal members giving appearance of Fig. 4 and yielded breakdown values of from 130 to 145 kv.

For convenience in manufacture, it appeared advisable to so shape the metallic flux distributing terminals that a cylindrical spindle, rather than the shaped spindle of Fig. 4, could be used, if possible, without too great loss of breakdown values. An insulator was, therefore, constructed as shown in Fig. 5 with gilded wooden terminal flux distribution members. Under test, this showed absolutely no corona up to nearly 400 kv. and at 400 kv. broke down without sign of previous distress. Fig. 6 shows appearance at breakdown with

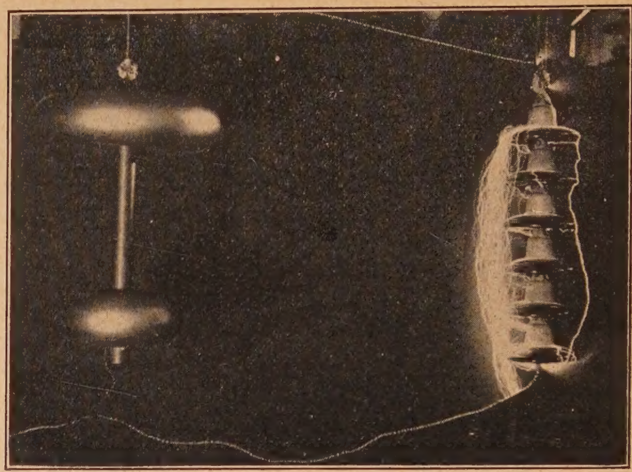


Fig. 7

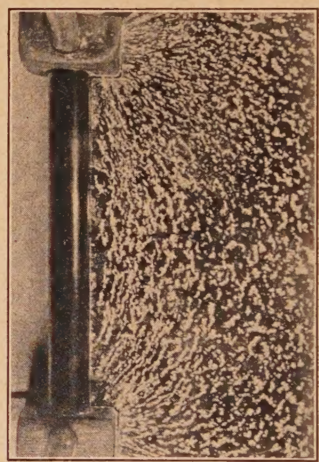


Fig. 8

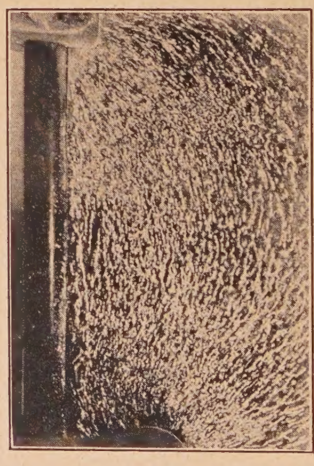


Fig. 9

no corona or arc along the insulating spindle. Hung in parallel with a string of six unit insulators of somewhat greater over-all length, results were as shown in Fig. 7 at 360 kv. and no sign of corona on the single unit.

These results gave encouragement for continued work and considerable effort was expended in the exploration of the surrounding fields and on the study of field forms secured with shredded asbestos. Fig. 8 shows the field form around a cylindrical spindle with metallic rods at each end and at right angles to the axis of the spindle. This is a condition which, clearly, does not give an insulating surface conforming to the lines of force of the

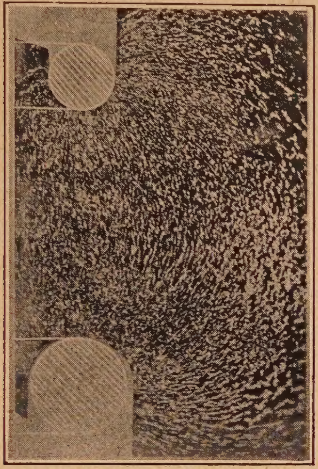


Fig. 10

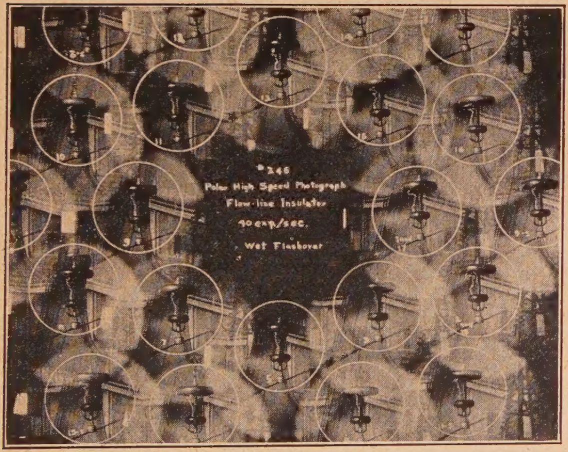


Fig. 11

field. Fig. 9 shows the effect of placing a metallic torus surrounding one end of the spindle. The field of force has flow lines more nearly conforming to the insulating surface. Fig. 10, with a torus surrounding each end of the spindle and concentric with its axis, gives a field with lines of force parallel with the surface of the insulating spindle throughout most of its length and also places the spindle in a hollow electric field where the strongest part of the field, with a maximum potential gradient, is a cylindrical belt immediately along the shortest path between the two toroidal surfaces and entirely surrounding the spindle.

Visual observation determined that with such arrangement undesirable corona formation did not occur up to about the breakdown voltage, but the eye could

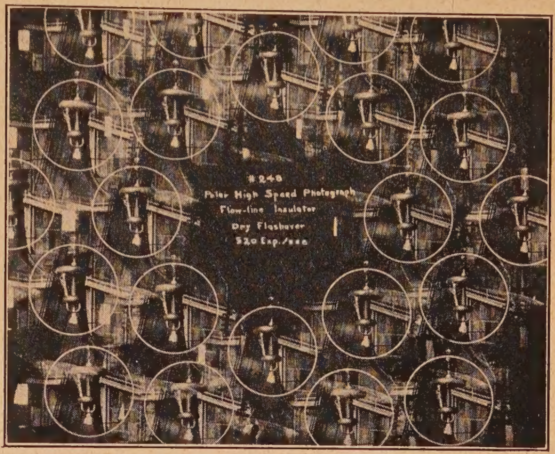


Fig. 12

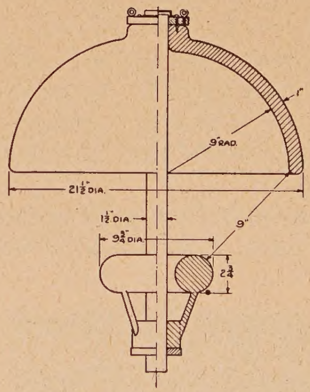


Fig. 13

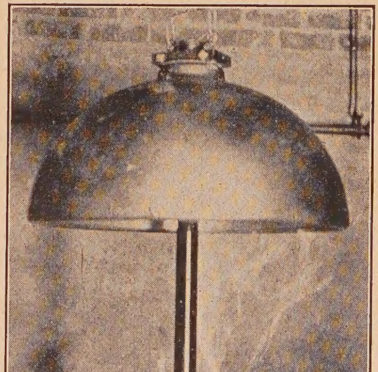
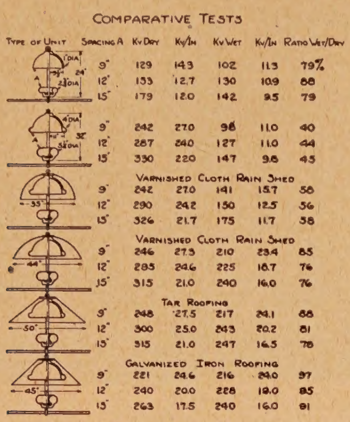


Fig. 14

not detect with certainty if static streamers or power arcs might not occasionally, and for an instant, traverse the surface of the insulating spindle. In order to determine this with certainty, polar high speed stereoscopic photo-

graphs were taken. Fig. 11 shows such a photograph at 48 exposures per second and Fig. 12 shows a similar photograph at 520 exposures per second. In no case was a streamer or arc formed along the insulating spindle nor could one be blown upon it by strong air currents. Up to this point no attempt had been made to secure results except under dry conditions, as it was believed



COMPARATIVE TESTS

Type of Unit	Spacing A	Kv Dry	Kv/In	Kv Wet	Kv/In	Ratio Wet/Dry
	9"	129	14.3	102	11.3	79%
	12"	153	12.7	130	10.9	88
	15"	179	12.0	142	9.5	79
	9"	242	27.0	98	11.0	40
	12"	287	24.0	127	11.0	44
	15"	330	22.0	147	9.8	45
Varnished Cloth Rain Shed						
	9"	242	27.0	141	15.7	58
	12"	290	24.2	150	12.5	56
	15"	326	21.7	175	11.7	58
Varnished Cloth Rain Shed						
	9"	246	27.3	210	23.4	85
	12"	285	24.6	225	18.7	76
	15"	315	21.0	240	16.0	76
Tar Roofing						
	9"	248	27.5	217	24.1	88
	12"	300	25.0	243	20.2	81
	15"	315	21.0	247	16.5	78
Galvanized Iron Roofing						
	9"	221	24.6	216	24.0	97
	12"	240	20.0	228	19.0	95
	15"	263	17.5	240	16.0	91

Fig. 15

that absence of complication of wet conditions would help to an understanding of the necessary fundamental relationships. The next step involved study of the modifying elements introduced by wet spray test and storm conditions.

A model corresponding to Fig. 13 was constructed and gave the appearance of Fig. 14 on breakdown. This

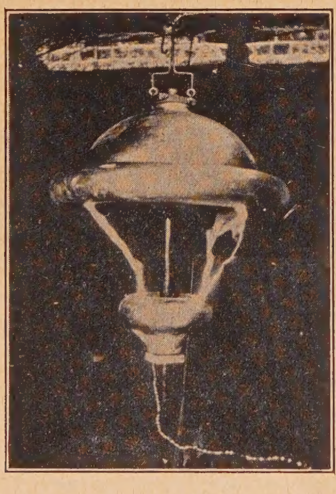


Fig. 16

did not yield as good results as hoped for, although the following results were obtained.

	Dry		Wet		
Spacing	Kv.	Kv./in.	Kv.	Kv./in.	Ratio
9 in.	201	22.3	102	11.3	51
12 in.	240	20.0	131	10.9	55

In order to determine the influence of the various factors involved, and to secure more favorable results, a long series of comparative tests was carried out on a variety of models and combinations. Of this series, a

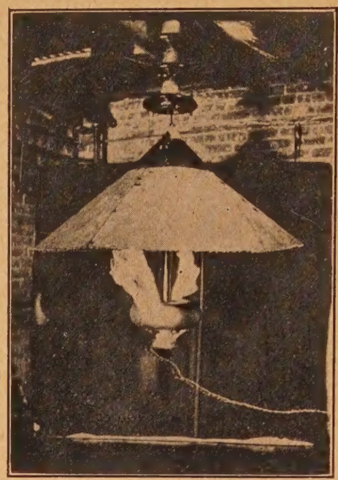


Fig. 17

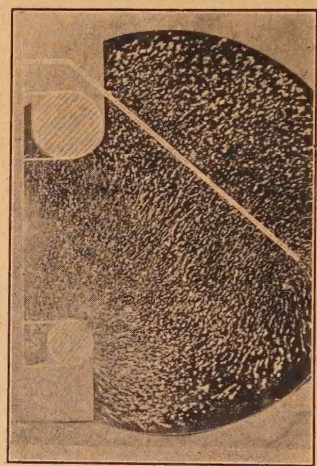


Fig. 18

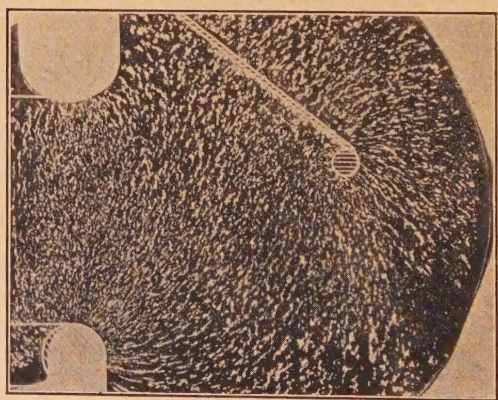


Fig. 19

few typical combinations and their results are given in Fig. 15. The appearance of two of these models, under arcing conditions, is given by Figs. 16 and 17.

These tests showed clearly the direction in which further development should proceed and a careful study

Fig. 20

Fig. 21

Fig. 22

of field forms was made on several models, in confirmation, and as shown in Figs. 18, 19, 20, 21, 22 and 23.

As a result of this, and work on other models, a final model of insulator was constructed in limited number with dimensions as shown in Fig. 24, for the collection of data under service conditions on high-voltage power lines with a variety of climatic conditions. The field

Fig. 23

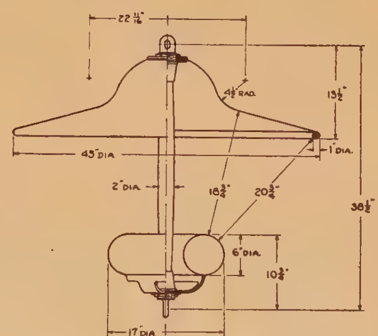


Fig. 24

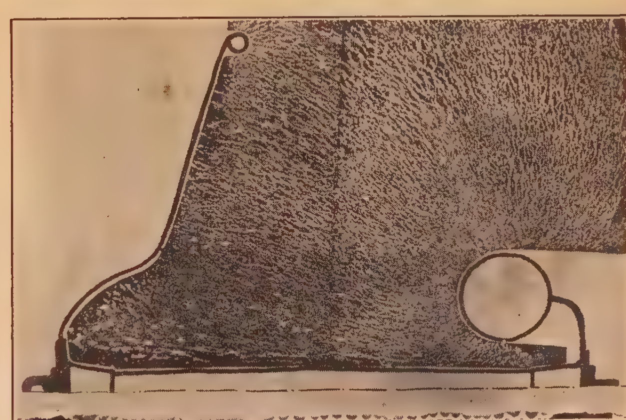


Fig. 25

form of this model is shown in Fig. 25. The appearance of this model, following severe snow conditions, is shown in Fig. 26 and under heavy arcing conditions at 280-kv. in Fig. 27.

With sufficient experience, under service conditions,

its rating can be established, or, if necessary, dimensions modified to meet any desired rating.

The test values on this insulator range at about 280 kv., or over, dry and 200 kv., or over, under standard wet spray test per unit. No corona is visible on any part of the insulator until within about five per cent of breakdown voltage. Two units in series require about 500 kv. dry or 350 kv. wet for breakdown. These values are without capacity modification which could be readily secured to improve these values.

FIG. 26

During the period in which the electrical features of this insulator have been under development, H. C. P. Weber, of the Westinghouse Research Laboratories, has been engaged in the development of impregnated and treated wood spindles for use in this insulator. His results are such that, with absence of corona and arcing conditions on the surface of the insulating member, there is definite promise of an insulating strain member with satisfactory dielectric properties and mechanical properties far superior to any porcelain yet available. The spindles used in demonstration tests accompanying this paper have been prepared under methods developed by Dr. Weber, but will not be further considered in a paper devoted to the electrical rather than the chemical features of this problem. Artificial aging and weathering tests of great severity accompanied by repeated electrical tests, extending over a number of months, have been applied to these spindles.

FIG. 27

Special acknowledgment should be made for the thorough cooperation and great assistance which has been rendered in this problem by D. F. Miner and H. W. Tenney, both of the Westinghouse Electric and Manufacturing Company, through work which they have carried out in Pittsburgh.

Acknowledgment should also be made for the interested and valuable assistance which has been given on this problem by assistants who have worked with the writer in Worcester at one stage or another of the development of the problem. These are R. H. Bryant, H. W. Tenney, A. W. Hill, D. E. Howes, O. B. French, R. M. Field, S. T. Chen, C. L. Denault, R. L. Kimball, R. D. Paul and E. Topanelian, Jr.

A QUANTITATIVE STUDY OF REGENERATION BY INDUCTIVE FEED BACK

The amplification of received radio signals by regeneration in electron tube circuits is well known. One method of regeneration is the feeding back of alternating current power by means of inductively coupled coils in the two circuits, from the plate circuit to the tuned circuit connected to the grid of the electron tube. This method has been used extensively in modern radio receiving sets and is known as the "tickler" method of regeneration. However, very little quantitative data have been available on the amplification produced by this method of regeneration.

By means of simple alternating current theory an equation has been derived from which the amplification produced by inductive feedback may be calculated. This equation shows that regeneration can be considered as producing a reduction in the resistance of the tuned circuit and so increasing the current. The equation derived was completely verified by experiment.

These experiments are described in Bureau of Standards Scientific Paper No. 487 "A Quantitative Study of Regneration by Inductive Feed Back" by C. B. Jollife and Miss J. A. Rodman. A copy of this paper may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Lightning and other Transients on Transmission Lines

BY F. W. PEEK, Jr.
Member, A. I. E. E.
General Electric Co., Pittsfield, Mass.

Review of the Subject.—*A great many uncoordinated researches and observations have been made of lightning on transmission lines both in the field and in the laboratory. It is the purpose of this paper to coordinate this work with a view of determining the various types and order of magnitude of predatory voltages to which transmission lines are subject. No claim is made for exact results. If it were possible to obtain such results, they could apply only to specific cases. A knowledge of the general types of disturbances and their order of magnitude should be of great value in determining the best means of providing against them. Failures of apparatus can be provided against in a number of ways, for instance, by excessive insulation; by less insulation but a design to prevent local high stresses; by prevention of high lightning voltages by placing the line under ground; by greatly limiting the possible voltage by a ground wire; by limiting the time of application of the high voltage by arresters; or by combinations of the above. Obviously, the matter of design and economics is also of importance in considering the problem of protection.*

The technical part of the discussion will not be limited to cloud lightning, but will cover other disturbances.

Recent work of the author with his lightning generator and model transmission lines with and without ground wire will be included.

Voltage of a Lightning Flash

THERE has always been speculation as to the voltage of a lightning stroke, and various estimates have been made in more or less complicated or indirect ways. Recent laboratory tests have shown that up to about 2,000,000 volts maximum, 150,000 volts is required for every foot of spark.[1] If this rule held for great distances, the voltage of lightning could be calculated, since the length of the lightning flash as well as the height of cloud, etc., can be estimated. It had been generally concluded, however, that the voltage of the stroke was very much less than would be indicated by the length of the flash, or that when the flash-over started, it in some way continued to great distances at relatively low voltages.

In a lecture before the Franklin Institute the author described an experiment which seems to offer an almost direct means of measuring lightning voltages.[2] The means is quite simple. When a lightning flash occurs within a certain distance of a transmission line, a certain percentage of the voltage of the bolt is induced on the line. The voltage of the bolt cannot be measured, but its distance from the line and height of cloud can be estimated. The actual voltage induced on the line can be measured by gaps or estimated from insulator flashovers. The author has measured lightning voltages on transmission lines in Colorado as high as 500,000; insulator flashovers by lightning have occasionally indicated voltages as high as 1,500,000 or more.

A model was made to scale representing cloud and transmission line for a certain observed condition. By means of the lightning generator it was found that when a flash occurred from this model cloud 1 per cent of its voltage was induced on the model line. But we know by observation that the voltage induced on an actual line, under similar conditions, is sometimes of the order of 1,000,000. If this is 1 per cent of the voltage of an actual lightning flash, the voltage of the flash must be 100,000,000 volts. (See Fig. 1). This gives a voltage of 100,000 per every foot of spark, (330 kv/m.) which, considering the possible error, indicates that the needle gap spark curve may hold even at these extreme voltages. While the field produced by the charge is fairly uniform, it is probable that at the instant before spark-over a needle-like streamer forms and breakdown then corresponds to the needle gap distance. Needle gap spark-over requires less than 20 per cent of the 30 kv./cm. required for a uniform field. The sparking distance should usually correspond to a continuous voltage because there is generally no large transient until after the spark starts.

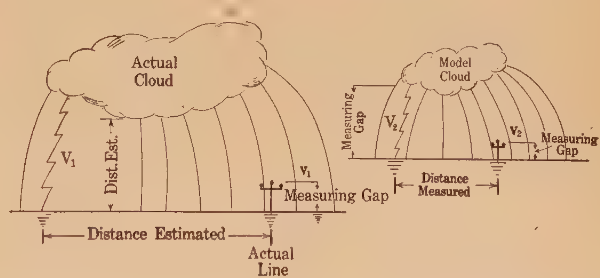


Fig. 1—Measuring the Voltage of Lightning

Measured or Estimated Height of Cloud. Distance to and Length of Flash. Voltage Induced on Line. Lightning Voltage not Measured.

Lightning Voltage Determined from V_1 and Known Percentage Induced on Line from Model

Model Line to Scale from Actual Line. Lightning Voltage and Induced Voltage Measured. Therefore Per Cent of Lightning Voltage Induced on Line is Known.

$$\frac{v_1}{V_1} = \frac{v_2}{V_2} \quad V_1 = \frac{v_1}{v_2} V_2$$

It thus appears by approximately direct measurement that the order of voltage of a severe lightning stroke to ground may be about 100,000,000. The lightning voltage during a storm will, of course, vary over a very

1. F. W. Peek, Jr., Tests at 1,000,000 Volts, *Electrical World* December 31, 1921.
2. F. W. Peek, Jr., High-Voltage Phenomena, *Journal* Franklin Institute, Jan. 1924.

To be presented at the Pacific Coast Convention, Pasadena, Cal., October 13-17, 1924.

wide range, sometimes much higher but generally lower than the value above. The author has observed that during a severe thunderstorm there may be many induced strokes at very low voltages, a less number at moderate voltages and so on to very few at the extreme voltages.

It will be noted that the above conditions require a gradient of 100 kv./ft. (330 kv./m.) in the most dense part of the dielectric field where the flash occurs, and a

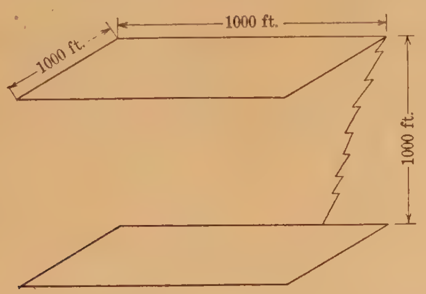


Fig. 2—"Cloud" Assumed for Calculation of Waves Shown in Fig. 3

gradient of less than half of this value a short distance from the flash. (See Fig. 4.)

Norinder has recently measured voltage gradients during a lightning storm which confirm the values given above.[3] To quote from his article in the *Electrical World*—"field intensities of the order of 100 kv. to 150 kv. per meter (30 to 45 kv./ft.) are common during thunderstorms at about the height of an ordinary transmission line. Pressures of 200 kv. per meter (60 kv./ft.) have also been recorded. A close study of the records shows that in the regions near the lightning path field intensities of the order of 300 kv. to 400 kv. per meter (90 to 120 per ft.) may exist." De Blois observed corona brushes of considerable dimensions. This also is an indication of gradients of the above order.

Nature of a Lightning Discharge

The experimental evidence seems to show that for the most part lightning discharges are impulses of very steep wave front, although some discharges are of impulses of slanting wave front and some are oscillatory. Oscillographic measurements made by De Blois on discharges from antennas showed that 60 per cent of the discharges were of steep wave front.[4] Similar studies recently made by Norinder indicate impulses of slanting wave front. However, it is not possible to tell from oscillographic records just how steep such waves are because of the relative slowness of the apparatus in responding. Other observations, however, indicate the order of the steepness of the wave front. When an impulse voltage is measured by a needle gap and a sphere gap, the sphere indicates approximately the true value of the voltage while the needle indicates a much lower value.[5] The ratio of these voltages indicates the steepness of the wave front. From observations on transmission lines the author has found impulses corresponding to single half cycle of 200-kv. sine waves and also impulses of very much greater steepness with an impulse ratio of two.

It is of interest to make certain assumptions as to size of cloud and length of discharge and calculate the wave to see if the above observations seem reasonable. Although such a check is quite rough, it should give good indications as to whether steep wave front impulses are likely to occur.

Assume that a cloud 1000 ft. (305 m.) square and 1000 ft. (305 m.) high, uniformly charged, discharges to earth. (See Fig. 2). The capacity of such a cloud is approximately 27×10^{-10} farads and the inductance of the path is 0.000488 henrys. If the resistance of the discharge path is 1000 ohms, the discharge is an impulse and non-oscillatory. The time is conveniently measured in microseconds. See Fig. 3, which is quite in agreement with observations. Fig. 3 also shows that the wave is practically an impulse with a resistance of 500 ohms for the discharge path, and that it is a damped oscillation for 100 ohms resistance. It is certain that

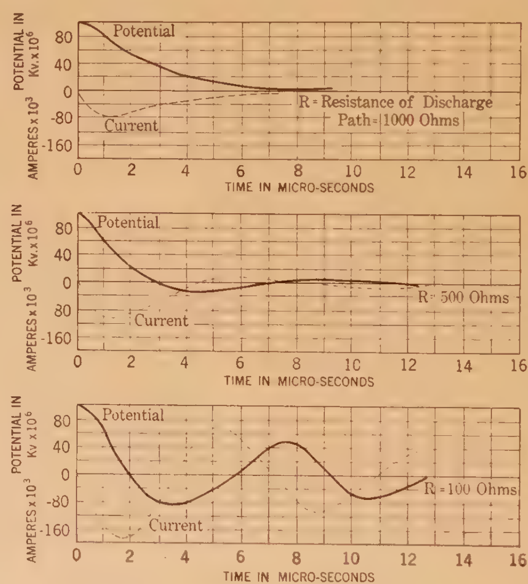


Fig. 3—Transients for "Cloud" Discharge to Earth (See Fig. 2)

$C = 27 \times 10^{-3}$ Microfarads
$L = 0.488 \times 10^{-3}$ Henrys

the cloud condenser is not as simple as the example taken and the probabilities are that there are local flashes in the cloud before the final flash occurs.

At 100,000,000 volts the maximum current would be 78,000 amperes. The stored energy would be 13,500 kw/sec.

3. H. Norinder, Electric Thunderstorm Field Researches, *Electrical World*, Feb. 2, 1924.

4. L. A. DeBlois, Some Investigations on Lightning Protection of Buildings, A. I. E. E., Vol. XXXIII, p. 519, 1914.

5. F. W. Peek, Jr., The Effect of Transient Voltages on Dielectrics, A. I. E. E. XXXIV, p. 1857; Lightning, *G. E. Review*, July 1916.

Lightning on Transmission Lines

Most lightning disturbances on transmission lines occur by electrostatic induction and not by direct stroke. A charged cloud causes an electrostatic field to earth. Part of the field will terminate on a transmission line within its area. The line is said to have a "bound charge." If the voltage between earth and cloud becomes high enough, a lightning flash will occur. Although this flash may be a mile away from the line, the charge on the line is released and the insulated line increases from earth potential to some value above with polarity opposite to that of the cloud. The effect is of a voltage suddenly applied between line and ground. The field that extended between line and cloud now extends between line and ground. The voltage wave travels over the line at the velocity of light. If the line insulators are strong enough or have a high enough impulse ratio, the impulse may travel to the powerhouse to break down apparatus or to be harmlessly discharged to ground over the arrester if it has low resistance and low impulse ratio. As this lightning wave travels over the line, it becomes gradually dissipated by losses. The voltage that the line assumes at the instant of discharge is that of the equipotential surface at the point in which the line is located. This is a certain percentage of the potential of the cloud above earth, or, in fact, a certain percentage of the voltage of the lightning bolt. In studies in Colorado, as already stated, the author has actually measured induced lightning voltages on transmission lines as high as 500,000 volts. Insulator flashovers have occurred that indicate induced voltages as high as 1,500,000 volts, although the greater percentage of voltages induced on transmission lines are very much lower than this. These figures as already shown afford a means of estimating the voltage of a lightning flash.

Lightning Voltage vs. Height of Line. Fig. 4 shows the lines of force from a charged cloud. Transmission lines of equal height are shown, one right under the cloud and others some distance away. It will be noted that for the line under the cloud the gradient is 100 kv/ft. (330 kv/m.) but that it is much less a short distance away. The gradient is high immediately under the cloud. It will also be noticed that the voltage for any line will vary approximately as the height of the line because the field over the relatively short distances is approximately uniform. No attempt is made, because of the scale, to show the flux terminating upon the line. When a discharge takes place from cloud to ground, the line takes the potential of the equipotential surface in which it is located. The induced lightning voltage on a transmission line thus varies approximately as the height of the line. It is also approximately equal to the height of the line times the voltage gradient. Note that the voltage decreases very rapidly with increasing distance from the cloud.

Maximum Possible Induced Lightning Voltage on a Transmission Line. It was shown above that the maximum possible voltage gradient during a lightning storm was about 100 kv./ft. (330 kv./m.). This gradient would determine the voltage induced on the line if it were directly under a cloud charged to a voltage sufficient to discharge it to earth or to the line. Generally this condition will exist only in cases of direct stroke and gradients for very severe storms will be of the order of 50 kv./ft. (165 kv./m.) while for the majority of storms, gradients will be much lower than this. Low gradients will also exist for cloud to cloud discharges, which are generally in the majority.

It is of interest to tabulate height of tower vs. theoretical maximum voltage at values for very severe storms. The voltages in Table I were found by multiplying the height of tower by the gradient caused by the cloud. In the second column, the maximum voltage was found by using a gradient of 100 kv/ft. As previously stated, this is the gradient necessary to cause the lightning flash, and can only apply to the line when it is directly under the storm center. The voltages in the third column were found by using a gradient of 50 kv/ft. Such a gradient occurs when the line is about 1000 ft. from the storm center. It is a severe condition and does not usually occur. In column 4, a gradient of 100 kv/ft. was used, while a gradient of 50 kv/ft. was used in columns 5 and 6. All these conditions are severe and unusual. The voltages are for the instant that the flash occurs, and before possible insulator arc-overs can take place. These figures are, of course, not exact, but probably give the order of the voltage that might occur on a badly exposed line in a very severe storm directly over the line. Data obtained in Colorado for 24 miles of a badly exposed line on a high mountain ridge showed only one or two direct strokes in a season of fifty severe storms. Of the many lightning impulses induced on the line very few exceeded 50 kv. during a storm.

Referring to Table I, note that the ground wire practically cuts the voltage values in half. The ground wire will be very completely considered in a later section. The lightning spark-over voltages for insulators and bushings are given in the last column.[6] It will be noted that a 220-kv. line is generally free from lightning voltages high enough to cause insulator flash-overs.

Propogation of Lightning on Transmission Lines. A laboratory study was made of the propogation of lightning on transmission lines.[7] These tests show that the voltage decreases in value and becomes less steep as the lightning impulse travels along a line. On striking an end, it increases in voltage and steepness of wave front as it is reflected. When an impulse strikes an inductance or choke coil, part is reflected but the voltage on the far side may increase to several times the in-

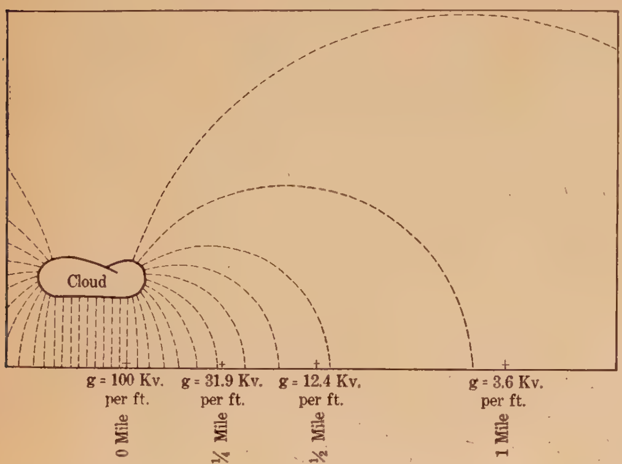
6. F. W. Peek, Jr. The Effect of Transient Voltages, A. I. E. E., Vol. XXXIV, p. 1857, The Insulation of High Voltage Transmission Lines, *G. E. Review*, Feb. 1922. High Voltage Power Transmission, A. S. C. E. Vol. LXXXVI, p. 725.

7. F. W. Peek, Jr., The Effect of Transient Voltages, III, A. I. E. E., June 1923.

TABLE I
LIGHTNING VOLTAGES ON TRANSMISSION LINES

Height of Tower Ft.	No Ground Wire		Ground Wire			Lightning Flash-over Voltage of Line		
	Theoretical Highest	Probably Usual Highest	Direct Stroke to Ground Wire (One Wire)	Usual Highest (One Ground Wire)	Usual Highest (Three Ground Wire)	200 Kv. Line	154 Kv. Line	110 Kv. Line
75	7500	3750	3750	1875	900	..	..	..
50	5000	2500	2500	1250	625	1800	..	..
40	4000	2000	2000	1000	500	1800	1400	900
30	3000	1500	1500	750	375	1800	1400	900
20	2000	1000	1000	500	250	..	..	..

For a grounded line, the voltage above ground just before the discharge would be zero. For an isolated system the line would not assume the above voltage before the discharge as there would be leakage over the insulators and arresters and much "static." There would also be a reduction of the static voltage by the section of the line not under the clouds.



Distance from point directly beneath cloud	g.	Voltage induced on a line twenty ft. high
0	100 kv. ft.	2000 kv.
0	3.19 "	638 "
½ "	12.4 "	248 "
1 "	3.6 "	72 "
2 "	0.9 "	18 "

Cloud 1,000 ft. above earth and at a potential of 100,000,000 volts.

FIG. 4—ELECTRIC FIELD AND POTENTIALS IN SPACE CAUSED BY CHARGED CLOUD

coming wave. This is not the case if the choke coil is shunted by resistance. A large choke coil without resistance may be a source of danger.

The corona loss in a line helps to lower the voltage of the wave. This was noted by measuring the voltage as the wave traveled along the line.

High Frequency and Oscillations Due to Secondary Discharge, Switching and Arcing Grounds. When an insulator is arced over or a break occurs to ground, an oscillation takes place. In 1907 and 1908 the author conducted some tests in the mountains of Colorado for E. E. F. Creighton and J. A. Clay.[8] A 24-mile idle line was available. The lightning was permitted to discharge to ground through a large gap in series with a small auxiliary gap in a dark box. A rapidly revolving photographic film on a steel disk recorded the discharge. Many of these discharges were photographed. In all cases, following the first impulse, a very highly damped oscillation took place at the natural period of the line or about 1900 cycles. Fig. 5 gives an example of one of the many records taken. A few of the records are given in Table II.

TABLE II
DURATION AND FREQUENCY OF A LIGHTNING DISCHARGE FROM A TRANSMISSION LINE
("High Line" 24 mi. Long)

Film No.	Half Oscillations	Duration Seconds	Frequency	Gap Setting Voltage to Ground Kv.	Fuse Blown
1a	12	0.0031	1930	20	
1b	6	0.0018	1660	20	
2a	8.5	0.0022	1930	20	
2b	8.5	0.0025	1700	20	Multiple Stroke
	6.5	0.0017	1880		
2c	4.5	0.0013	1730	20	
2d	5	0.0016	1560	20	Multiple Stroke
	4.5	0.0014	1600		
2e	5	0.0017	1470	20	
2f	6	0.0017	1800	20	
2g	6.5	0.0019	1700	20	
3a	10	0.0031	1600	20	1 strand 0.0036
3b	9	0.0029	1550	20	Multiple stroke
	6	0.0026	1500		
4a	1	0.0002	2000	35	1 strand 0.0036
4b	1	0.0002	2000	35	
4c	1	0.0002	2000	35	
4d	1	0.0002	2000	35	
4e	1	0.0002	2000	35	
4f	1	0.0002	2000	35	
5a	8	0.0020	2000	20	
5b	7	0.0019	1840	20	
5c	11	0.0026	2100	20	1 strand 0.005 broken
5d	7.5	0.0020	1850	20	

The duration values given in Table II are a measure of the duration of the secondary oscillations and not of the lightning stroke. The "duration" measurements by De Blois are of the same order 0.006 seconds, while measurements by Norinder are of the order of 0.05 seconds. This instrument did not record the first impulse but the oscillation following the arc-over. Other observations indicate that in general there is the very steep impulse, followed, when breakdown occurs, by a highly damped oscillatory discharge of the line at its natural period. This oscillation is of comparatively low frequency.

8. E. E. F. Creighton, Measurements of Lightning, A. I. E. E., Vol. XXVII, p. 669.

When there is an arcing ground, especially on a non-grounded delta system, oscillations occur. As far as can be observed, these oscillations are damped and have the effect of lightning impulses.[9] They rarely reach double voltage on a transmission line but may reach higher values when confined by inductance coils and may build up high local voltages in transformers. Although large numbers of tests have been made by producing arcs on power systems, undamped oscillations have not been observed. Fortunately, the severe oscillations produced by arcs on non-grounded systems are disappearing with the adoption of the grounded neutral system. With the grounded neutral systems the oscillations of arcing grounds are no longer a problem.

Disturbances due to switching are of the same nature as impulses or damped oscillations.

The reason that oscillations are highly damped seems apparent. Corona loss increases as the square of the excess voltage above the starting voltage and directly

FIG. 5—LIGHTNING DISCHARGE FROM TRANSMISSION LINE PHOTOGRAPHED ON REVOLVING FILM

as the frequency. A simple calculation shows that it would require thousands of kilowatts at high frequency to supply the high-frequency loss on a comparatively short line at voltages considerably below the high-frequency flash-over voltage of a line insulator. Furthermore, with arcs to ground or between lines the oscillations could not be isolated to short sections of a line. This also applies to damped oscillations of high train frequency.

High-frequency low-voltage undamped oscillations can exist and do exist locally on transmission lines. Such oscillations have been observed at towers where there were incipient arcs due to loose connections on the insulators or to faulty units in a string. The energy of such oscillations is necessarily low, since it is caused by the discharge of the very small capacity of the insulator. Probably the principal harm that these oscillations can cause is disturbances in carrier current systems.

A full size 220-kv. tower with insulators with and without grading rings was set up in the laboratory to try to obtain high-frequency voltages by arcs. The short section of line was excited at 60 cycles. To simulate a line, the high-voltage condensers from the impulse generator were inserted between the short line and ground. The dampening of such an arrangement should be much less than on a transmission line of similar capacity. In considering available energy it must be remembered that breakdown is caused by voltage. A large condenser with low losses in a short line can maintain the voltage more readily than the capacity of a long leaky line. Arcs made on the condensers failed to cause the insulators to arc-over. Loose contacts were made on insulator strings and varied to cause incipient arcs as well as arcs of considerable length. There was no measurable increase in voltage. A frequency meter showed a frequency of about four million cycles and very low voltage for local insulator arcs. Corona discharges five feet in diameter at a million volts failed to cause any measurable increase in voltage. Arc-over at normal voltage was readily caused by dirt.

TABLE III

ACTUAL DIMENSIONS OF MODEL LINES

Dimension of Cloud: 5 ft. by 7½ ft. (152 cm. by 229 cm.) Horizontal plate with rounded edges

Height of Cloud above Ground: 43½ in. (112 cm.) unless otherwise stated

Height of Line	Size of Conductor	Spacing
	Diameter	
12 in. (30.5 cm.)	0.040 in. (0.102 cm.)	3 in. (7.6 cm.)
6 in. (15.2 cm.)	0.020 in. (0.051 cm.)	1½ in. (3.8 cm.)
3 in. (7.6 cm.)	0.010 in. (0.025 cm.)	¾ in. (1.9 cm.)
1½ in. (3.9 cm.)	0.005 in. (0.012 cm.)	⅜ in. (0.9 cm.)

Ground Wire: Same size as line wire and, unless otherwise stated, conductor spacing from nearest conductor.

Lightning Generator Constants: Resistance 5000 ohms. Cap $= 1.31 \times 10^{-3}$ mf. $L = 2.88 \times 10^{-2}$ mh.

It is, of course, possible to apply persistent oscillations or damped oscillations of high train frequency to a short section of transmission line by means of a powerful oscillator. The effects of such voltages are quite characteristic and unlike anything that has been observed on a practical line. (See page 708). Insulators are not punctured and shattered, but cracked by excessive heating. At some sharp point on the line large corona losses cause great hot streamers. The ionization persists from cycle to cycle or train to train. If this point is removed or covered with porcelain, a similar arc starts at some other place where the gradient is high. These hot streamers or "electric needles" cause arc-over at about half of 60-cycle arc-over voltage.[10] To produce the thermal effect and to reduce the insulator

9. G. Faccioli, Electric Line Oscillations, A. I. E. E., Vol. XXX. W. W. Lewis, Switching Operations, *G. E. Review*, Oct. 1913. F. E. Terman, Measurement of Transients, A. I. E. E., Vol. XLII, p. 462.

10. F. W. Peek, Jr., Dielectric Phenomena in High Voltage Engineering, McGraw-Hill.

flash-over voltage, the oscillations must persist for a relatively long time. Although high-voltage persistent oscillations or oscillations of high train frequency do not occur on transmission lines, they are of interest in an academic way and make a spectacular demonstration.

The arc-over voltage is always higher for the types of oscillatory voltages that occur on transmission lines than it is for 60-cycle voltages.

Oscillation may cause high local internal voltages to build up in transformers.[11]

The Ground Wire

Quite an extensive laboratory study has been made on the protective value of the ground wire. This investigation was made on a model in which size of conductor, conductor spacing, height of line, etc., were all reduced to scale.[12] The results show quite conclusively that under favorable conditions the ground wire offers a very high degree of protection for both induced and direct strokes. Under such conditions and practical conductor arrangements it is possible to reduce induced lightning voltages to one-third of the value of those induced on unprotected lines. Under these conditions the ground wire also offers almost complete protection against direct strokes. When it is possible to obtain the value of protection mentioned above, the higher voltage lines will be practically immune from insulator flash-overs due to lightning.

Some very interesting theoretical studies of the ground wire have been made.[13] Methods of making the calculations are also found in text books.[14] In general, the experimental work checks the theoretical work. There have been many conflicting reports from operating companies as to the protective value of the ground wire. Probably approximately half of the reports are in favor and half against the ground wire. The reason for this seems to be apparent from this investigation. The ground wire gives the high value of protection mentioned if the ground is good and the reactance of the ground connection is low. In a dry country, with poor grounds, its protective value against induced strokes would be low. On the other hand, in a damp country its protective value should be high. Its protective value would be low if grounds were made infrequently, since there would then be a considerable length of wire or reactance between the ground wire and the ground connection.

Complete data are given in the tables for the various factors affecting the ground wire. These will be discussed in detail.

Induced Strokes. The arrangement for studying induced strokes on transmission lines is shown in Fig. 6. The plate represents the position of the cloud which causes a steady electrostatic field to ground in the vicinity of the transmission line. The complete cloud includes the condenser of the lightning generator. This field is in reality a 60-cycle a-c. field but at the instant

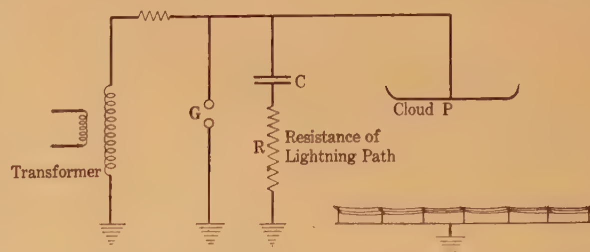


Fig. 6—Connections Used in Studying Induced Voltages on Transmission Lines

of discharge of the clouds to earth is in effect a steady field. Due to this field, all points in the intervening space have a definite potential. The space in the vicinity of the line has a certain percentage of the lightning potential above earth. When the condensers discharge, the charge on the transmission line is released and the line assumes the potential of the equi-potential surface in which it is located. See Fig. 4. The voltage of the cloud P and of the transmission line can be accurately measured; the voltage of the cloud to ground by spheres and the voltage of the lines to ground by small needle gaps mounted to give minimum capacity. The ratio of the conductor diameter to spacing, etc., was selected to correspond to practical conditions. Tests were made with the transmission line grounded through high resistance to represent the grounded neutral system and also without grounds. The results

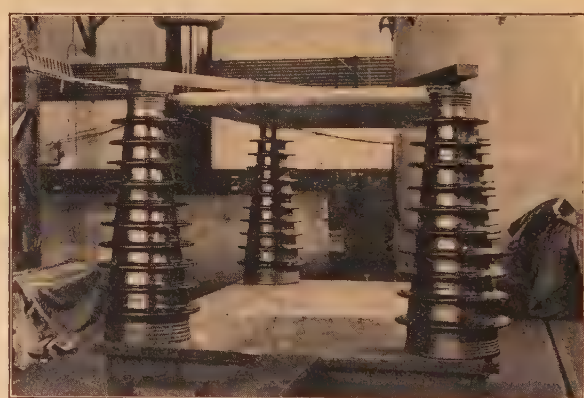


Fig. 7—Study of Voltage Induced upon Transmission Lines. Illustration Shows Overhead Cloud and a Section (to Scale) of one of the Lines Studied During the Investigation

11. J. Murray Weed, Prevention of Transients in Windings, A. I. E. E., Sept. 1915, Feb. 1922. L. F. Blume and A. Boyajian, Abnormal Voltages in Transformers, A. I. E.E., Feb. 1919.

12. F. W. Peek, Jr., High Voltage Phenomena, Franklin Institute, Jan. 1924.

13. W. Peterson, The Protective Value of the Ground Wire, E. T. Z., Jan. 1914. E. E. F. Creighton, Theory of Ground Wires, A. I. E. E. 1916, p. 948.

14. E. J. Berg, Electrical Engineering, Advanced Course, McGraw-Hill.

were practically the same. The model cloud and line are shown in Figs. 7 and 8.

The actual height of cloud is not important. It can be readily shown mathematically that since the field is practically uniform between the line and earth the induced voltages depend only on the voltage gradient in this part of the field. A given voltage gradient may be caused by a high cloud and high-cloud voltage or a low cloud with low-cloud voltage. Any condition may thus be simulated by a fixed cloud distance and varying voltage.

FIG. 8—SHORT SECTION OF A THREE-PHASE LINE WITH OVERHEAD GROUND WIRE UPON WHICH A STUDY WAS MADE OF INDUCED VOLTAGES OF LIGHTNING. ILLUSTRATION SHOWS ONE OF THE "TOWERS" AND ONE OF THE SPARK-GAPS USED TO MEASURE VOLTAGE AT THIS POINT

TABLE IV
PROTECTIVE VALUE OF THE GROUND WIRE

Induced Voltages on Transmission Lines With and Without Ground Wire Line by Scale 30 ft. (9.1M) Conductors Spaced 7.5 ft. (2.3 m.) Size 1.2 in. (3 cm.) Lightning Voltages 372 Kv.

Arrangement	Scale Distance to Cloud above Line	Induced Voltage	Per Cent of Lightning Voltage Induced on Line	Protective Ratio of Ground Wire Voltage with Ground Wire / Voltage without Ground Wire
No ground wire o o o	216ft.(66m.)	33	9	
Ground wire above center o line o o o	216ft.(66m.)	14.7	4	0.43
Three ground wires above o o o line o o o	216ft.(66m.)	8.7	2.3	0.26
No ground wire o o o	864ft.(264m.)	8.0	2.1	..
Ground wire above center o line o o o	864ft.(264m.)	3.4	0.9	0.43
No ground wire o o o	Irregular Field	6.3	1.70	
Ground wire o o o o	"	3.3	0.9	0.52

TABLE V
EFFECT OF GROUND WIRE ARRANGEMENT

Arrangement	Height of Line		Voltage induced on Line		Protective Ratio
	Actual of Model	To Scale	Actual of Model	To Scale	
No ground wire O←S→O←S→O	6in. (15.3cm.)	30 ft. (9.2 m.)	29.8	1788	..
One ground wire... dist; "S" above center wire. . o o o	" "	" "	14.3	858	0.48
Two ground wires.. . . o o o	" "	" "	10.2	612	0.34
Three ground wires. . . . o o o	" "	" "	7.3	438	0.24
One line wire...... 4 ground wires . . o . .	" " " "	" " " "	1.7	102	0.06
One line wire 3 ground wires..... . o .	" "	" "	4.7	282	0.16
One ground wire S/2 above center wire............	" "	" "	12.9	774	0.43
One ground wire 2S above center wire............	" "	" "	17.0	1020	0.57
Four ground wires.. . s . s o s o s o s . s .	" "	" "	2.7 2.7 2.7		0.09 0.09 0.09
Three ground wires. . A B C . o o o .	" "	" "	A7.2 B4.2 C7.2		0.24 0.14 0.24
Three ground wires. . o o o . .	" "	" "	7.2 5.2 7.2		0.24 0.18 0.24

$s = 1\frac{1}{2}$ in.

By reducing the line spacing, size of conductor and height to scale, the capacity and inductance *per unit length* remain practically the same as for the full size line. The only factor that does not correspond is the resistance. It is relatively higher. However, it is not believed that this materially affects the results. It might also be well to point out that with equal voltage gradients the induced voltage will be much lower in the model than on an actual line. This follows because the voltage is approximately equal to the height of line times the gradient.

The length of the artificial cloud has no particular meaning except that it is long enough to produce a practically uniform field.

It will be noted from Table IV that the protective

value of the ground wire is quite high and the same for all cloud heights as theory would indicate. With one ground wire the voltage is practically cut in half. This also conforms with theory. The last column in Table IV is called the protective ratio. A ratio of 0.43 means that the induced voltage on the line with a ground wire is 0.43 of that on a line without a ground wire.

Ground Wire Arrangement. Table V shows the effect of various ground wire arrangements in limiting the lightning voltage. This table gives sufficient data to estimate the value of any practical arrangement.

TABLE VI
COMPARISON OF INDUCED LIGHTNING VOLTAGES ON GROUNDED AND NON-GROUNDED NEUTRAL SYSTEMS

Line Arrangement	Height of Line		Voltage Induced on Line		Protective Ratio of Ground Wire
	Actual of Model	To Scale	Actual of Model	To Scale	
No ground wire	6in. (15.3cm.)	30 ft. (9.2 m.)	29.8	1788	..
Ground wire above center line	" "	" "	14.4	864	0.48
No ground wire power lines grounded through resistance ("neutral grounded")	" "	" "	33.1	1986	..
Ground wire "neutral grounded"	" "	" "	14.7	882	0.45

Under favorable conditions one ground wire reduces the voltage to one-half; two to one-third and three to one-fourth. The effectiveness of the ground wire increases as the distance between it and the line wire is decreased. The protective ratios given above are for a spacing equal to the conductor spacing which closely approximates the practical condition.

Fig. 9—Effect of Resistance and Inductance upon the Protection Offered by an Overhead Ground Wire

Comparative Value of Ground wire on Grounded and Non-Grounded Neutral Systems. Table VI shows that the ground wire is equally effective on grounded and non-grounded neutral systems. It is interesting that the induced voltage is generally slightly higher on grounded neutral systems.

Variation of Induced Voltages and Effectiveness of Ground Wires for Lines of Different Heights. Table VII shows that by doubling the height of the line the

TABLE VII
COMPARISON OF INDUCED VOLTAGES FOR CONSTANT CLOUD AND DIFFERENT HEIGHTS OF LINE

Line Arrangement	Height of Line		Voltage Induced on Line Kv.		Protective Ratio of Ground Wire	Average Gradient near Line	
	Actual of Model	To Scale	Actual of Model	To Scale		Kv. ft.	Kv. M.
No ground wire	6 in. (15.3 cm.)	30 ft. (9.2 m.)	23.3	1398	..	46.6	152
Ground wire above center of line	" "	" "	11.0	660	0.47	..	..
No ground wire	12 in. (30.5 cm.)	60 ft. (18.3 m.)	48.7	2922	..	48.7	159
Ground wire above center line	" "	" "	24.0	1440	0.47	..	..

TABLE VIII
EFFECT OF CLOUD VOLTAGE

Arrangement	Height of Line		Voltage Induced or Line		Protected Ratio of Ground Wire	Lgt. Voltage Per Cent
	Actual of Model	To Scale	Actual of Model	To Scale		
No ground wire	6 in. (15.3 cm.)	30 ft. (9.2 m.)	33.0	1980	..	100
Ground wire	"	"	14.7	882	0.45	"
No ground wire	"	"	16.2	972	..	50
Ground wire	"	"	7.3	438	0.45	"
No ground wire	"	"	8.2	492	..	25
Ground wire	"	"	..	..	..	"
No ground wire irregular field	"	"	6.3	378	..	..
Ground wire irregular field	"	"	3.3	198	0.52	..

lightning voltage *induced on the line is approximately doubled.* The protective ratio of the ground wire is not changed with change in the height of line. Table VIII shows that the protective ratio is independent of cloud voltage.

Effect of Type of Discharge on The Value of the Ground Wire. So far, the results discussed have been for voltages induced by cloud to cloud or cloud to ground discharge with a steady field between cloud and line at the instant previous to discharge. A quite different type of discharge might occur. There might be a cloud at near ground potential directly above the line, while above this cloud there might be another at a very high potential. See Fig. 10. A discharge between these clouds could in turn cause an impulsive discharge between cloud and ground. This would induce a voltage on the line. A model of this arrangement was made with the results as given in Table IX. The protective value of the ground wire is the same as for the other types of discharge.

Relative Values of the Ground Wire Where the Soil is Conducting and Non-Conducting. The Effect of Inductance or Resistance in Series. Tests were made to determine the relative value of the ground wire when used in countries with dry and damp soil. A long box with a metal bottom was filled with 6 in. of sand. The 6 in. line was placed upon the top of the sand. Referring to Table X, the first two tests were made with a metal plate on the surface of the sand as a conducting ground. The next three tests were made with the sand ground and with the "water level" below the surface at a distance equal to the height of the line. By comparing tests 1 and 3, it is seen *that under equal conditions the induced voltage is higher in dry countries.* This follows because the flux extends from cloud to water level.

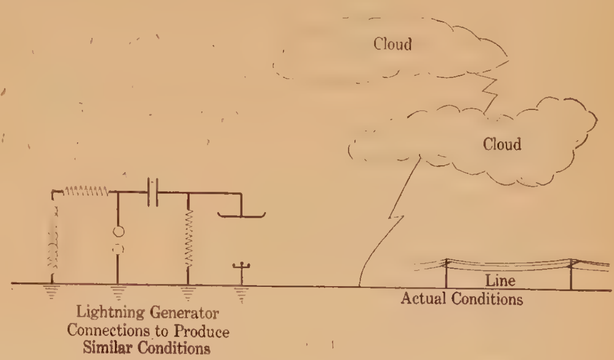


Fig. 10—Impulsive Discharge (Discharge takes Place from Upper to Lower Cloud then from Lower Cloud to Ground)

The effect is that of increasing the height of line. Test 4 shows that the ground wire is effective providing connections are made to water level. Test 5 shows that it is not effective with a poor ground connection.

The ground wire reduces the voltage by reducing the initial charge or the flux terminating on the line and by

TABLE IX

COMPARISON OF INDUCED LIGHTNING VOLTAGES FOR CLOUD TO GROUND DISCHARGE AND IMPULSIVE DISCHARGE FROM CLOUD TO CLOUD

Line Arrangement	Height of Line		Voltage Induced on Line		Protective Ratio of Ground Wire	Average Gradient before Discharge	
	Actual of Model	To Scale	Actual of Model	To Scale		Kv./ft.	Kv./m.
No ground wire..................	6 in. (15.3 cm.)	30 ft. (9.2 m.)	23.0	1380	..	46	150
Ground wire above center line......	"	"	11.1	666	0.48	..	..
*No ground wire..................	"	"	17.9	1074	..	0	0
*Ground wire above center line.....	"	"	8.2	492	0.46	..	..

*Impulsive discharge to "dead" cloud above line and to ground. See Fig. 10.

TABLE X

COMPARISON OF INDUCED LIGHTNING VOLTAGES WITH CONDUCTING AND NON-CONDUCTING SOILS

Line Arrangement	Height		Nature of Soil	Voltage Induced on Line		Protective Ratio of Ground Wire	Average Gradient near Line	
	Actual of Model	To Scale		Actual of Model	To Scale		Kv./ft.	Kv./m.
No ground wire..................	6in. (15.3cm.)	30 ft. (9.2 m.)	Conducting	33.0	1980	...	66	216
Ground wire above center line......	"	"	"	14.7	882	0.45	..	..
No ground wire..................	"	"	Top dry sand 6 in. to water level	37.0	2220	..	74	..
Ground wire above center line. Grounded at water level..........	"	"	Top dry sand 6 in. to water level	19.8	1188	0.53	..	..
Ground wire above center of line. Poor ground made by driving nail in sand..........................	"	"	"	34.6	2078	0.98	..	..

TABLE XI
EFFECT OF RESISTANCE IN "GROUND"

Arrangement	Height of Line		Voltage Induced on Line		Resistance or Reactance	Protection Ratio
	Actual of Model	To Scale	Actual of Model	To Scale	Ohms or Milli-henrys	
No ground wire....................	6 in. (15.3 cm.)	30 ft. (9.2 m.)	33.1	1990	∞	..
Ground wire above center—Resistance in series with ground connection....	"	"	15.7	942	0	0.47
	"	"	18.4	1100	855	0.55
	"	"	20.0	1200	1430	0.60
	"	"	17.5	1050	1700	0.53
	"	"	24.9	1500	4400	0.75
EFFECT OF REACTANCE IN GROUND WIRE						
No ground wire....................	6 in. (15.3 cm.)	30 ft. (9.2 m.)	33.1	1990	∞	..
Ground wire above center—Induction coil in series with ground connection.	"	"	13.8	828	0.08	0.42
	"	"	16.6	995	0.11	0.50
	"	"	18.4	1100	0.13	0.55
	"	"	14.8	888	0.46	0.45
	"	"	25.0	1500	0.98	0.75
Long wire line to ground............	"	"	13.8	828	10′ *	0.42
	"	"	13.8	828	50′	0.42
	"	"	17.4	1045	100′	0.52

*Length in feet.

increasing the capacity to ground. This capacity has in series with it, however, the inductance and resistance of the ground connections. If the lightning discharge took place without time, the initial instantaneous voltage would be the same with or without the ground wire. The tests so far have shown that there is sufficient delay so that the inductance does not produce an appreciable effect with short wire connections. Inductance was added to the ground wire connection with the result shown in Fig. 9. Tests were also made with long ground connections and with series reactance. They show that the protective value of the ground wire could be greatly reduced in practise by resistance in the ground connection or by considerable distance between grounds causing high inductance. Thus, in a long span the induced voltage would be highest in the center of the span and minimum at the tower.

The actual values of resistance and inductance used, as well as length of ground connections, are given in Table XI. These values do not apply directly to a practical line, since the voltage and the energy on the actual line would be much higher. It is difficult to correct these to equivalent conditions for an actual line. It is safe to say that the values should be much smaller than those indicated to make an effective ground wire. They emphasize the importance of short low resistance low reactance ground connections. Fortunately, the modern steel tower affords a low inductance path to ground.

Electromagnetic Induction. The voltages measured in the line wires protected by ground wires are made up of the electrostatic induction and electromagnetic induction due to the induced current in the ground wire. The electromagnetic induction was found to be negligible. High impulse currents from the lightning generator were sent through the ground wire. The voltage induced on the line was 400 volts per ft. per 1000 amperes.

Direct Strokes. The ground wire, if favorably installed, is undoubtedly of great value in case of direct strokes. In the experimental work on direct strokes, the voltage was increased so that the discharge would take place almost directly over the ground wire. It will be seen by referring to Table XII that the ground wire offers good protection from direct strokes. There seems to be greater chance for an unprotected line to be struck in a dry country than in a wet country. In these tests the connection used was that in Fig. 6.

TABLE XII
PROTECTIVE VALUE OF GROUND WIRE FOR DIRECT STROKES

Arrangement	Number of Strokes Applied	Number Striking Line	Number Striking Ground Wire	Number Striking Ground
Connections Fig. 6				
No ground wire. Conducting soil. No needle on cloud..............	105	14	..	82
Ground wire. Conducting soil. No needle on cloud..................	102	0	35	67
No ground wire 6 in. sand. No needle on cloud.....	102	59	0	
Ground wire 6 in. sand. No needle on cloud.....	102	1	76	
No ground arcs 3 in. sand. Needle on cloud........	104	91	..	
Ground wire 3 in. sand. Needle on cloud........	102	0	96	
Connections Fig. 10				
No ground wire. Needle on cloud conducting soils..................	100	100	..	
Ground wire. Needle on on cloud. Conducting soils..................	100	2	98	

Tests were also made with the impulsive discharge of Fig. 10. It is interesting that this type of discharge was early recognized by Lodge. It is more difficult to predict where this type of discharge will strike than for the steady discharge. In these tests about 2 per cent of the hits struck under the ground wire to the line. The data will be found in Table XII. It appears that the ground wire will give almost complete protection against direct strokes on the line.

These tests indicate why direct strokes are so rare in practise. With everything deliberately arranged for the spark to take place to the line projecting above a "plain" it very frequently took place elsewhere. In practise the chances of a direct stroke would be very small, first, because the cloud arrangement would not be deliberate and, second, because the chances would be lessened by trees, hills, etc. The same would apply to high induced strokes because they necessitate a very high-voltage cloud near the line. Here, too, hills and valleys would be helpful.

Insulating to Withstand Lightning Voltages

Lightning Breakdown Voltage of Apparatus

Transient voltages are more likely to cause concentration of stress in apparatus containing inductance and capacity than normal frequency voltages. In designing inductive apparatus to withstand lightning voltages, the problem is greater than merely putting enough insulation between line and ground to withstand the highest probable lightning voltage as in the case of the insulator string. This has been recognized in the use of heavy end turn insulation in transformers. However, it is not always possible or economical to insulate local turns or coils to withstand the full voltage of a lightning impulse. It is obviously of great importance to design apparatus so that transients do not concentrate on a few turns but divide evenly over the total insulation. This has been done by shields.

Fig. 11—Lightning Striking the Overhead Ground Wire of a Transmission Line During Study of Direct Strokes and Induced Lightning Voltages on a Three-Phase Line during a Lightning Storm

Shields have a preventative action like the ground wire. Two good examples will be mentioned here. The ring insulator shield is used at high voltages to distribute the normal frequency stress more uniformly. By its use, the operating stress is reduced to about 25 per cent of the stress on a non-shielded string. The maximum lightning stress is also reduced to 25 per cent of that for a non-shielded string.

There is great danger of concentration of stress in transformers. At the first instant that lightning strikes a tranformer, the coils act as if they are open circuited;

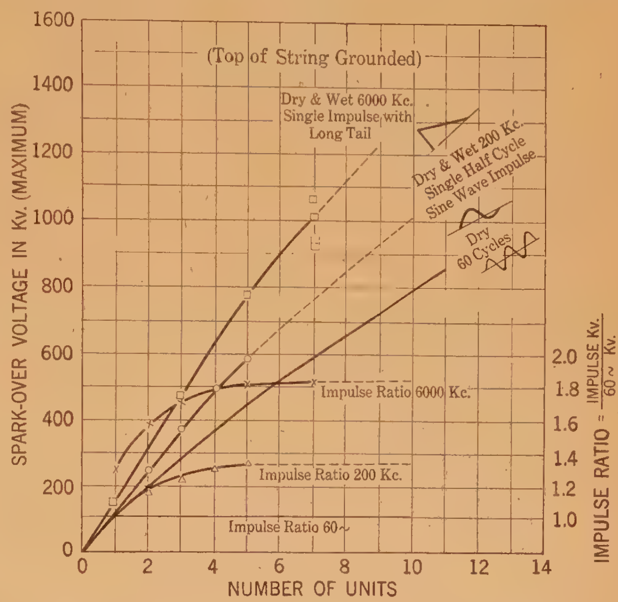


Fig. 12—Comparison of 60-Cycle and Lightning Flash-over Voltage on Suspension Insulators

only the capacities function and the transformer is in effect a string of capacities or insulators with capacities to ground to cause unbalance. By placing a proper shield on the line end the effect of the capacities to line is to neutralize the capacity to ground and there is no voltage concentration. The transformer shield differs from the insulator shield in that the insulator shield controls the stress at both normal and transient operation, whereas the transformer shield operates only for transients.

The general principle of shielding is to place the coil between shields so that the electrostatic field established by the transient causes each turn to take the same relative stress as it does at normal frequency. An oscillation is thus not possible. The shield is of equal value in preventing high voltages from building up locally on the apparatus by high-frequency oscillations on the line. If even voltage distribution is obtained the problem is simplified.

For lightning strokes, switching surges and other high-voltage transients that occur on transmission lines, the breakdown voltage is much higher than for 60 cycles. The range of these surge voltages is given for line insulators in Fig. 12. The highest values represent steep wave front lightning voltages. For such voltages the wet and dry arc-over values are the same.

The steeper the wave front or the higher the frequency the higher is the breakdown voltage.

Persistent oscillations cause breakdown at decreasing voltages with increasing frequency, if the ionization persists from cycle to cycle. Hot electric needles are formed which reduce the spark-over voltage. However, as already stated, because of excessive losses, such oscillations cannot reach high values on transmission lines. This also applies to damped oscillations of high train frequency. Where the train frequency is over about 1000 cycles the breakdown voltage begins to decrease below the 60-cycle value with increasing train frequency. On transmission lines a damped train of oscillations may occur for each half cycle. The train frequency is then 120 per second. The breakdown and spark-over voltages are higher than for the 60-cycle. The breakdown voltage for the oscillation of the "Tesla Coil" excited at 60 cycles is also higher than the 60-cycle breakdown voltage.

Oscillations on a line can only follow after an arc occurs. Thus the original break must always occur in

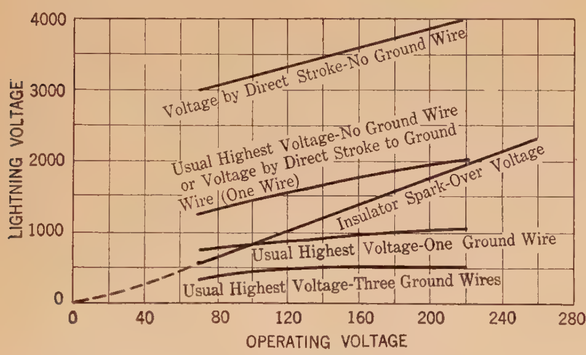


FIG. 13—COMPARISON OF INSULATOR ARC-OVER VOLTAGE WITH MAXIMUM LIGHTNING VOLTAGE FOR SEVERE STORM DIRECTLY OVER LINE

some other way as by lightning or by dirt or faulty construction. It is important to prevent the initial failure. Failures by dirt have been too frequently attributed to high frequency.

The lightning breakdown voltage of liquid and solid insulations is often five or more times the 60-cycle value when the stress is equally distributed.

The lightning flash-over voltage of insulators is plotted with operating voltage in Fig. 13. On this same figure are plotted curves of the probable highest lightning voltage for lines with and without ground wires. A direct stroke on a line without a ground wire causes voltages much higher than the insulator arc-over voltage. The second curve down represents the usual highest voltage on a line without a ground wire. It happens that this same curve corresponds to the voltage by a direct stroke on a line with one ground wire. This curve crosses the insulator spark-over voltage curves for an operating voltage of 220 kv. This indicates that a 220-kv. line without a ground wire is not likely to have insulator trouble from lightning except in case of direct stroke. It further indicates that a 220-kv. line with a favorably installed ground wire is not likely to have trouble from lightning under any circumstance. The next curve gives the usual highest voltage for a line with one ground wire. Under usual conditions very little trouble should be expected for lines insulated for over 100 kv. operation. The lowest curve shows that three ground wires reduce the probability of lightning trouble to still lower operating voltages. The probability of trouble with direct strokes would be reduced in proportion.

The values of voltages taken in the above curves are for the most severe storms directly over exposed lines. Such conditions might not occur during a year or several years. It is a well established fact that during any storm there are likely to be many low-voltage induced impulses, a less number of moderate voltage impulses and frequently none at high voltage.

LIGHTNING ARRESTERS

The methods for guarding against lightning so far discussed have been preventative, such as the ground wire; better distribution of stress by the shield and by extra insulation. The remaining method is the arrester.

The object of the arrester is to permit transient or other excess voltages above a given value to discharge to earth and to suppress the dynamic arc and prevent oscillations. Since the transient currents are likely to be very high an efficient arrester must have low resistance. An arrester must also have low time lag, otherwise the transient voltage may rise to high values before the discharge occurs. A good arrester is of unquestionable value at the low and moderate operating voltages. The question of the extent of its use to take care of the unusual conditions at the very high voltages is an economic one.

Because arresters have gaps they cannot prevent low-voltage oscillations from building up high voltages in transformers. However, there is very little to be feared from such trouble in modern apparatus with shields. Where special cases require it, such oscillations are readily absorbed by placing a resistance in series with a condenser without a gap across the line.

CONCLUSIONS

Voltage and Energy of a Lightning Flash. The voltage of a severe lightning flash is probably of the order of 100,000,000. The current may be 78,000 amperes and the stored energy 13,500 kw./sec. The discharge is usually non-oscillatory and often takes place in a few microseconds.

Voltage Disturbances on Transmission Lines. Most lightning disturbances on transmission lines are steep wave front impulses that occur by electrostatic induction. There may also be impulses of slanting wave front and damped oscillations. The lightning arc-over of insulators is always higher than for 60 cycles and is not greatly affected by moisture.

The usual induced voltage is probably below 1000 kv. The voltage increases almost directly with the height of the line. The maximum possible voltage can be estimated by multiplying the maximum gradient of 100 kv./ft. by the height of the line in feet.

A lightning wave travels over the line and is dissipated to a considerable extent by corona loss. When it strikes an inductance or the end of the line it increases in value and is reflected. If the inductance is not shunted by resistance, high values of voltage may be built up. When breakdown occurs there is a damped oscillation at the comparatively low frequency of the natural period of the line or some section of the line.

Switching surges and other high-voltage disturbances that occur on transmission lines are damped oscillations. Such disturbances always require a higher voltage to cause insulator flash-over than 60 cycles.

Persistent or continuous undamped oscillations at high voltage cannot exist on transmission lines because of the enormous losses. This also applies to damped oscillations of high train frequency.

A high-frequency oscillation requires an arc. It is, therefore, a secondary disturbance following a breakdown caused by lightning, dirt or some defect. Oscillations are not serious on grounded neutral systems.

The Ground Wire. A single ground wire when properly installed under favorable conditions reduces the induced lightning voltage to 48 per cent of that without a ground wire; for two ground wires the reduction is to 34 per cent while for three ground wires it is to 24 per cent.

The reduction is the same for isolated and grounded neutral systems.

The ground wire is apparently not effective in a dry country unless grounds can be made in conducting soil. Induced lightning voltages are higher in a dry country than in a wet country.

The effectiveness of a ground wire decreases as the resistance or inductance of the ground connection increases.

The ground wire is also a good protection against direct strokes.

Insulating to Withstand Lightning Voltages—Lightning Breakdown of Apparatus. Insulating inductive apparatus to withstand lightning voltages is a greater problem than simply adding insulation. Shields to prevent localization of stress are important and function in a manner somewhat similar to the ground wire.

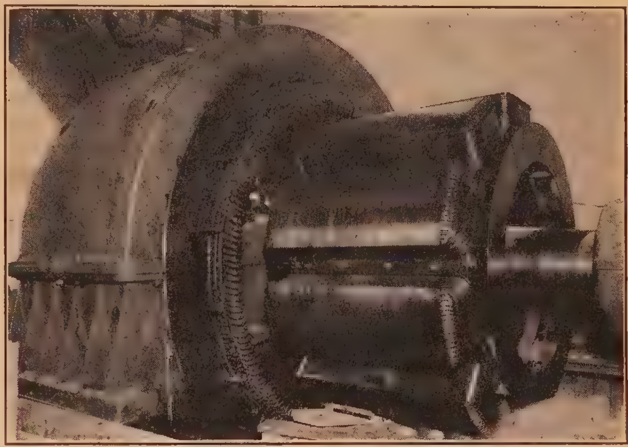
A plot of the lightning strength of insulators and the probable highest lightning voltage for different operating voltages is given in Fig. 13. The indications are that a 220-kv. line with a ground wire should be almost free from lightning troubles. It cannot be said that there is any definite voltage where immunity begins, since the unusual may always happen. The danger becomes less and less with increasing operating voltage.

The extent to which protection should be used is a combined engineering and economic problem. The technical problem, which has been the subject of this discussion, is to determine the strength of apparatus, and the voltages to which it is likely to be subjected. With these factors known, the economic problem is to balance the cost of insurance against the value of better service and reduced liability of trouble.

WORLD'S LARGEST FREQUENCY CHANGER

By W. B. West
Associate, A. I. E. E.

Among the outstanding features in the recent development of the Brooklyn Edison Company's power system is the installation of a 35,000-kv-a. frequency changer set which will be used for the purpose of exchanging power between their 25 and 60-cycle systems. It is located at the foot of Hudson Avenue, Brooklyn, New York between John Street and East River, and is adjacent to the Gold Street Station. At present it is connected directly between Gold Street and the 60-cycle transmission system with ties at 66th Street.



The Largest Frequency Changer in the World; Recently Installed in Brooklyn, New York by Brooklyn Edison Co.

In point of size, this frequency changer is the largest electrical unit in existence. The base measures 45 ft. by 22 ft. and 21 ft. from the bottom of the air intake to the top of the air discharge hood. The machine is, therefore, fully 21 ft. high from the foundations. The shaft upon which it revolves is 14 in. in diameter and the largest rotating part is 14 ft. in diameter. The total weight of the machine is 460 tons and the weight of the rotating part is 280 tons. The bearings, of which there are four, are cooled by circulating water continuously through jackets surrounding the bearing surfaces. In order to provide for easy starting, oil is pumped into the bearing and under the shaft so that the entire rotating part is lifted clear of the bearing and supported on a thin film of oil. Several oil pumps, working at a pressure of 1200 lb. per sq. in., are provided for this purpose. When running at full speed, the machine turns at 300 rev. per min. This is a peripheral speed of about two and three quarter miles per minute for the largest rotating part. Actual test shows that it requires 45 min. to coast from full speed to dead stop.

A New 20-16 in. Hot Strip Mill

BY NOBLE JONES
Works Manager, West Leechburg Steel Co.

and

G. P. WILSON
Member, A. I. E. E.
General Engineer, Westinghouse Elec. & Mfg. Co.

THE past few months has seen the completion of a new 20-16 in. hot strip mill in the plant of the West Leechburg Steel Company at West Leechburg, Pa. The mill is entirely new and designed to roll thin strips. The finishing stands are arranged in tandem in close proximity to each other so that the work on the thin metal is completed before it has time to suffer any great loss in temperature.

Mill Machinery

The millstands are arranged in two parallel rows as indicated in Fig. 1. The seven roughing stands which have 20-in. flattening and 23-in. edging rolls are in one continuous line and the two intermediate stands together with four finishing stands, all having 16-in. flattening rolls are in another continuous line.

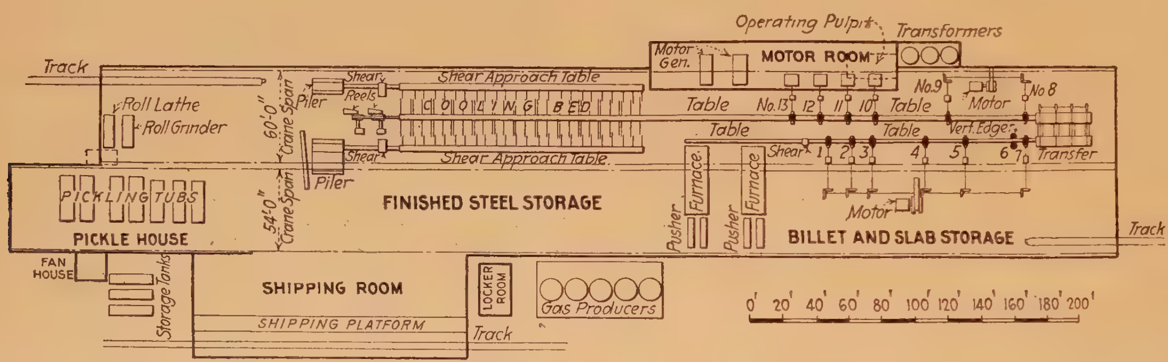


FIG. 1—GENERAL LAYOUT OF THE NEW STRIP MILL, SHOWING CONSERVATION OF SPACE AND BUILDING COST BY RUNNING THE STEEL BACK IN THE FINISHING MILL, PARALLEL TO ITS COURSE IN THE ROUGHING MILL

Incoming Line and Outdoor Substation Equipment

Power is purchased from the West Penn Power Company. This power is delivered to the mill through an outdoor substation shown in Fig. 5. Two overhead lines carrying 22,000 volts, three-phase, 60-cycle, feed this outdoor substation. Fig. 7 shows a single line diagram of the outdoor substation connection together with the indoor circuit to the mill equipment.

Power Transformer

The power transformers are located in the outdoor substation, and consist of three 3333 kv-a. oil-insulated, self-cooled, single-phase, 60-cycle, 2200/2300-volt transformers connected in delta on both the high-tension and low-tension sides. The low-tension buses are taken through the wall of the building and become the main bus of the 2300-volt substation structure inside the motor room. Power from this bus is distributed through suitable oil circuit breaker to the two 1500-horse power a-c. motors, driving the roughing and intermediate trains, and to two 2200-kw. motor-generator sets.

Motor Generator Sets

The two 2000-kw. 250-volt d-c. 514 rev. per min. 80 per cent power factor, 3-phase, 60-cycle, 2200-volts synchronous motor-generator sets are used to supply current to the common d-c. bus which supplies power for the mill motors and all auxiliary equipment. Each set consists of one synchronous motor and two 1000-kw. generators. These generators are designed for close voltage regulation from no load to full load and the regulation has so far been very good only a few volts difference between no load and full load. The machines are also designed to operate in parallel with a very even load distribution between the sets. The generators of each set are tied solidly in parallel. A 4000-A single-pole equalizer breaker is provided for the equalizing connection between the two sets. Fig. 13

FIG. 5—FRONT VIEW OF THE OUTDOOR SUBSTATION

Abridgment of a paper presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924. Complete copies to members on request.

shows the motor-generator set with the equalizer panel and its connection mounted between them.

Mill Motors

The mill proper and all auxiliary apparatus are motor driven. Stands 1, 2, 3, 4, 5 and 7 of the roughing train are driven by one 1500-horse power, 3-phase, 60-cycle 720 rev. per min., 2200-volt, a-c. wound rotor-type

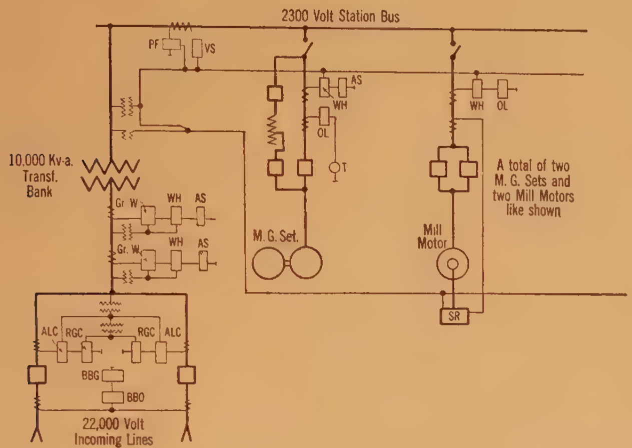


Fig. 7—Single-Line Diagram of the Outdoor Substation Connections and Indoor Substation Circuits to Mill Equipment

induction motor, through a reduction gear, counter shaft and gears to the individual stands. The metal in the roughing train is never in any two stands at one time. No attempt is made to obtain speed adjustment or speed regulation during the roughing passes. The pinion shaft of the gear set is provided with two 74-in. diameter, 31,500-lb. cast steel flywheels having a

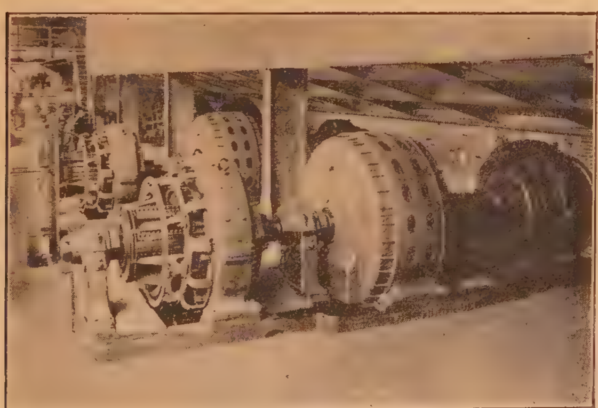


Fig. 13—A View of the Motor Room Substation Showing M-G Sets, Equalizer Panel, Motors, Etc.

combined rating of 25,000-horse power seconds at 720 rev. per min. The secondary of the motor is provided with an automatic liquid-type slip regulator which automatically increases the resistance in the secondary of the motor on heavy loads. Fig. 14 shows the motor installed complete with gear units, counter shaft and flywheels.

The vertical edging stand 6, which is located close to stand 7, is driven by a 100-horse power, 240-volt, d-c. compound-wound, adjustable-speed motor with a speed range of 400/800 rev. per min. Speed adjustment is required of this motor inasmuch as the steel will be in the edger and stand 7 simultaneously. The construction of this edger is shown in Fig. 15.

The intermediate stands 8 and 9 are driven by a 1500-horse power motor, duplicate of the one driving

Fig. 14—The 1500-Horse Power 705 Rev. per Min. Induction Motor Driving the First Set of Roughing Stands. The Control Gallery is Seen in the Background

Fig. 15—Vertical Edger

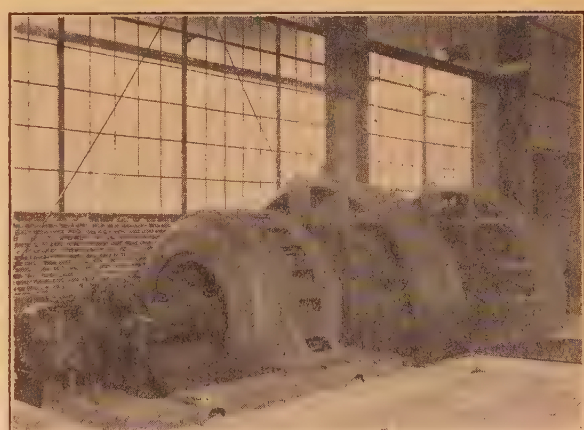


Fig. 16—The 1500-H. P. A-C. Motor Driving Intermediate Train

the roughing train through a reduction gear set, counter shaft and gears. The gear unit is equipped with two cast steel flywheels similar to the wheels on the roughing train gear. Fig. 16 shows the motor installed complete with the flywheel.

The four finishing stands 10, 11, 12 and 13 are individually motor driven. The first two of these stands 10 and 11 are each equipped with a 1500-horse

power, 240-volt, d-c. 125/250 rev. per min. compound-wound adjustable speed motor. The last two stands 12 and 13 are each equipped with 1800-horse power, 240-volt, d-c. 165/350 rev. per min. compound-wound adjustable speed motors. Fig. 17 shows one of 1500-horse power motors driving stand 11.

In every instance the steel product rolled in this mill is in at least two of the finishing passes simultaneously. On most products, especially the lighter gages, the steel strip is in the last four passes. This means, of course, that the correct speeds of the individual stands must be maintained very close to avoid stretching or breaking the strip or excessively looping it. No speed regulating devices are used to maintain the flat speed regulation required from no load to full load on the motors. Successful operation is entirely obtained by the good speed regulation in the motors themselves.

The distinctive feature of the mill is the tandem arrangement of the finishing stands, which takes the

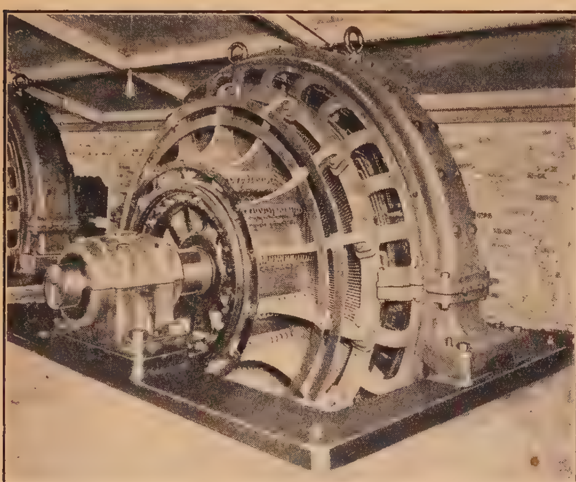


FIG. 17—THE 1500-H. P. 250-VOLT D-C. MOTOR DRIVING STAND No. 11 OF THE FINISHING TRAIN

piece before it is reduced to a thin section and finishes it before it has an opportunity to lose its heat. On cross country mills, or on mills where the metal is transferred from one stand to another, it is found that thin sections lose their heat and it is often difficult to reduce the steel to gages required. To overcome this objection it was decided to place the finishing stands near each other and in tandem. If these four finishing stands were driven through bevel gearing from one common motor the draft taken in each stand would have to be proportioned, so that the same volume of metal would leave each stand in a given time. This is necessary to avoid a large accumulation of a loop or pulling of the steel between stands. This difficulty was obviated by the use of an adjustable speed d-c. motor for each stand. With this arrangement it is possible to draft the steel as desired, since there is no mechanical connection between the individual stands.

In order to obtain reasonable tonnages out of a mill where thin sections are rolled and also to finish the steel as quickly as possible while it is still hot, it is desired to roll at a comparatively high speed. This makes it necessary to use considerable care in the design of the motors used and for this reason these machines have been constructed with compensating winding so that their speed is practically constant, regardless of the load which they are carrying. The motors are liable to be operating at any speed within a range of 2 to 1, the 1500-horse power motors having a speed range of 125 to 250 rev. per min. and the 1800-horse power motors a speed range of 165 to 350 rev. per min. Their rheostats may be adjusted so that they operate at any point within this speed range, and it is essential that the motor retain its speed even though the load instantly increases from friction load, which may be 5 per cent of its rating to some degree of overload. This is accomplished to a very close degree, although it will be noted from the load and speed ratings that there is an instantaneous drop which is largely recovered at the instant the metal enters the rolls. This only lasts for a period of approximately a second, as this time is required for the series field to build up its magnetic effect and restore the speed of the motor to its final value. This instantaneous drop in speed has the effect of building up a slight loop between stands which is of considerable advantage. If the motor maintained its high speed at the instant the steel entered the roll it would be necessary to set its speed somewhat lower, so as to gradually accumulate this loop. This, of course, would not be as desirable as to have it instantaneously develop a loop and then maintain its speed at the value desired. Table I shows

TABLE I
SHOWING THE SPEED REGULATION OF THE FINISHING STAND MOTORS WHEN ROLLING NARROW GAGE MATERIAL

Rolling 6⅜ in. by 0.065 in. from 3 in. by 7 in. by 5 ft. 3 in. Billet

	No. 10 Mill	No. 11 Mill	No. 12 Mill	No. 13 Mill	
Motor Amps	4000	3300	4000	4000	
Speeds					
No Load	136	181	235	292	
Momentary Drop	131	176	226	285	Piece Entering Mill
Rolling Speed	134	180	231	290	
Over Shot	140	188	240	296	Piece Leaving Mill
Voltage at Switchboard					
Light Load	250				
Momentary Drop	248				
Rolling Load	250				
Over Shot	254				
Gage & Temp. (F°) of Strip					
Entering	0.237	0.140	0.100	0.080	
Leaving				0.065	
Entering	1800°	1765°	1713°	1645°	
Delivery Speed—Approx. 1228 Ft. per Min.					
Finished Strip—Approx. 266 Ft. Long					
Above Speed with Voltage Correction					
No Load	136	181	235	292	
Rolling Speed	134	180	231	290	
Per cent Diff. between No Load and Rolling Speed	1.5	0.5	1.8	0.7	

the speed regulation of the mill when rolling steel under normal conditions. These speeds were taken at random and no effort was made to adjust the apparatus to obtain good results.

Part of the drop in speed is readily seen to be due to the momentary drop in voltage of the generator. This momentary voltage drop does not affect the speed relation of the various stands, inasmuch as all the motors are connected to a common bus and therefore are all affected alike. Table II is similar to Table I except that the data were taken when rolling wider strips.

The effect of the voltage drop on the speed is shown in the lower table of these figures and are values of speed on the basis of constant voltage. From these values the speed regulation of the motors themselves may be determined.

The load on the generators and the power required on the motors when rolling various size strips may be seen in Table III. A number of readings was taken on the different pieces of the same schedule and the readings shown are average results.

The above data in Table III may be used for determining or checking the horse power rating of the motors required to drive the individual stands of this mill or other mills, rolling similar products at similar speed and reduction. The size of the motors for this installation was determined from test data taken on mills rolling a product similar to that which was expected to be rolled by the mill. As an example to show how these data may be used, the following calculations are given for driving stands 11, 12 and 13 of this particular mill:

Stands	Area before Pass	Area after Pass	Difference in Area	Length before Pass	Volume Displaced
11	7-15/16 by 0.14 = 1.110	7-15/16 by 100 = 0.795	0.31	6,900	214
12	0.794	0.635	0.16	9.500	152
13	0.635	0.515	0.12	11,900	142

Horse Power Seconds	Time required for Pass—Sec.	Rolling Horse Power
5875	7	840
6600	7	940
6600	7	940

The above calculations are based upon the meter readings of the individual motors when rolling the 7-15/16 by 0.065 material listed in Table III. The voltage at the motor terminals is assumed to be 250 volts and constant throughout the load period on the motor. From a study of the above figures it is readily seen that the work done by the motors is displacing a certain volume of steel in a given time. The energy required for driving the motors to displace the metal is represented by the horse power seconds listed for the different stands. Knowing the speed and diameter of the mill rolls, it is easy to determine the time required for the steel to pass between the rolls, or in other words, the rate at which the metal is displaced. In this particular case it required seven seconds for each pass with the mill speed as given in Table III. The horse power of the motor is, therefore, the horse power seconds divided by the time. The last column in the above calculation gives these horse powers.

The rate at which the work is done in displacing the steel is dependent upon the speed at which it is rolled.

TABLE II
SHOWING SPEED REGULATION OF THE FINISH STAND MOTORS WHEN ROLLING WIDE GAGE MATERIAL

Rolling 16 in. by 0.065 in. from 3 in. by 2 ft. 7½ in. Billet					
	No. 10 Mill	No. 11 Mill	No. 12 Mill	No. 13 Mill	
Motor Amps	4000	4000	4000	4100	
Speeds					
No Load	139	167	196	215	
Momentary Drop	134	161	191	210	Piece Entering Mill
Rolling Speed	138	166	194	214	
Over Shot	144	172	202	220	Piece Leaving Mill
Voltage at Switchboard					
Light Load	242				
Momentary Drop	240				
Rolling Load	244				
Over Shot	250				
The Above Speed with Voltage Correction					
No Load	139	167	196	215	
Rolling Speed	136.8	154.6	192.4	212.2	
Per cent Diff. between No Load and Rolling Speed	1.5	1.5	1.75	1.25	

TABLE III
SHOWING POWER REQUIREMENT ON THE MOTORS DRIVING THE FINISHING STANDS, WHEN ROLLING VARIOUS SIZE STRIPS

Gage	Width	Motor for Stand 10			Motor for Stand 11			Motor for Stand 12			Motor for Stand 13			Billet 5.5
		Draft 0.140			Draft 0.100			Draft 0.080			Draft 0.065			
		Speed	Amps.	H. P. Seconds	Speed	Amps.	H. P. Seconds	Speed	Amps.	H. P. Seconds	Speed	Amps.	H. P. Seconds	
.065	7 15/16	137	2000	4690	165	2500	5,875	195	2800	6,600	221	2800	6,600	3 by 8 by 2 ft. 7½ in.
.065	9 7/8	139	2100	4710	165	2500	5,875	193	3600	8,450	219	3400	8,000	3 by 10 by 2 ft. 7½ in.
.065	10½	145	2300	5400	166	2100	4,950	197	4000	9,400	221	2800	6,600	3 by 12 by 2 ft. 7½ in.
.065	12½	145	2600	6100	173	4200	9,900	208	4200	9,900	245	4200	9,900	3 by 14 by 2 ft. 7½ in.
.065	12 13/16	145	2400	5650	177	4700	11,000	215	4000	9,400	236	3600	8,450	3 by 14 by 2 ft. 7½ in.
.065	13	145	2400	5650	172	4500	10,600	209	3800	8,950	230	4000	9,400	3 by 14 by 2 ft. 7½ in.
.065	15 11/32	142	2800	6600	176	5200	12,200	213	4600	10,800	226	3400	8,000	3 by 17 by 2 ft. 7½ in.
.065	15 9/16	142	3500	8200	176	5500	12,900	213	4000	9,400	228	3000	7,100	3 by 17 by 2 ft. 7½ in.
.065	16	139	3900	9200	167	3900	9,200	196	3600	8,450	215	4600	10,800	3 by 17 by 2 ft. 7½ in.

TABLE IV
AUXILIARY MOTORS USED AT 16 IN. HOT MILL

Location	No. of Motors	Type	Type of Winding	H. P.	Service Volts	Speed
Furnace Pushers	4	Mill	Series	20	230 d-c.	600
No. 1 Furnace Table Motor	1	"	Compound	40	230 d-c.	540
No. 2 Furnace Table Motor	1	"	"	20	230 d-c.	650
Roughing Mill Table Motor	1	"	Series	60	230 d-c.	475
Table Rolls at Transfer	2	"	"	20	230 d-c.	600
Rope Transfer	1	"	Compound	20	230 d-c.	650
Table Rolls No. 8-10 Passes	2	"	Series	20	230 d-c.	600
Furnace Blowers	2	Constant Speed	Compound	30	230 d-c.	975
Hot Bed-Center Runout Rolls	83	3-Phase	Induction	1/2	220 a-c.	375 at 25 cycle
Hot Bed Kick off	1	Mill	Compound	20	230 d-c.	650
Hot Bed Shuffle Bars	2	"	"	20	230 d-c.	650
Hot Bed Ratchet Bars	2	"	"	40	230 d-c.	540
Hot Bed Side Table Rolls	4	"	Series	20	230 d-c.	600
Vertical Shears	2	Constant	Shunt	20	230 d-c.	850
Shear Runout Rolls	2	Mill	Series	12	230 d-c.	700
PilerRolls	2	Variable	Shunt	10	230 d-c.	600/1200
Piler Sprockets	2	"	"	10	230 d-c.	600/1200
Coiling Reels	2	"	"	15	230 d-c.	600/1200
Coiling Machines	3	"	"	20	230 d-c.	850/1350
Pickle Machines	2	Constant	Comp.	20	230 d-c.	850
Vertical Edger	1	Variable	Compound	100	240 d-c.	400/800

In the above example the speed of 11 stand is 165 rev. per min. The mill, however, is designed to roll this narrow gage material at a much higher speed than given in these calculations, inasmuch as the motor has a maximum speed of 250 rev. per min. Therefore, the horse power required to roll the steel at this top speed will be 250/165 of 840 or 1275 horse power. This figure includes the friction load of the mill. In this particular installation the friction load was assumed to be 50 horse power, therefore, the actual net horse power required of the motor when rolling the above size of material at the top speed is 1225 horse power and the motor selected for this particular stand was 1500 horse power. The margin will permit safety factor and allow for low temperature steel and different size products.

Some of the products rolled on this mill would require more horse power than given above for the narrow material, if they were rolled at the top speed. These products, however, cannot be rolled at the maximum speed of the motor, but at some lower speed within the range of the motor rating. Nothing would be gained in tonnage in rolling these larger products at a higher speed, inasmuch as the furnace capacity limits the output of this mill. Knowing, therefore, the different size products which the mill is to roll and the hourly tonnage capacity of the furnace, the speed range of the motors may be definitely determined and selected for any particular installation. The products on this particular mill permitted a selection of a motor for stands 10 to 11 having a speed range of 125 to 250 rev. per min. and stands 12 and 13, motors having a speed range of 165 to 360 rev. per min.

Table III may also be used to determine the power consumption of the individual stands of this mill if the hourly tonnage capacity of the furnace is known. In this particular installation the maximum capacity of the two furnaces is 40 tons per hour. However, during the time in which the mill has been operating only one furnace has been used and this not to its maximum capacity. The mill has been operating on single turn of 10 hours and during the few months in which it has been in operation the power consumption has been on the average of approximately 118 kw. hours per ton of steel rolled. This figure includes all the power used by the main drive and the auxiliaries as well as the lighting in this mill. It is safe to say that the auxiliaries and lighting are 20 per cent of this total figure, therefore, the

Fig. 18—Internal View of the Mill Operator Gallery Showing Control Desk and Field Rheostat for the Machines

actual kw. hours per ton used by the mill motors are approximately 82 kw. hr. per ton. This figure no doubt will be decreased when the mill is run on double turn, which it is expected to do within a very short time.

Operator's Pulpit and Control Desk

The control of the mill motors and the d-c. end of the motor-generator set is accomplished from a control desk located in a gallery above the motor room. Fig. 18 shows an interior view of the gallery and gives a very good idea of the location of control desk and field rheostats for the various machines. This gallery is well up in front and centrally located so that the operator has a full view of all the stands of the mill. The push buttons and rheostat hand wheels for the machines are mounted on the top of the desk and the meters on an incline portion at the back side. The field switches for the various motor fields are located on the front side of the desk.

High-Voltage Circuit Breakers

The Operator's Viewpoint—Giving Practises, Experiences and Opinions

BY J. S. JENKS
Member, A. I E. E.
West Penn Power Co., Pittsburgh, Pa.

THE practises of the station operator in regard to circuit breakers are largely governed by his previous experience, his system and conditions on his system. For instance, a very large system may cover a very large area and have a very great capacity connected, but be of such a character that there is very little interconnecting, with very simple switching, and it may have no very great power capacity concentrated at any one point. On the other hand, the system may be very great in power capacity and cover such a small area that the potential of the system is rather low, and on account of the dependability of low potential and the lack of the necessity of numerous ties, the concentration of power is easily limited. In the first case, we find potential so high, and the breaker has to be so large to safely handle the potential, that lightning is not much of a factor, and the current is so small that it is really insignificant in such a large breaker. In the second case, the currents are greater and the breakers of necessity have to be large and substantial to withstand the great magnetic stresses, but such systems generally are confined to a small, closely built area, largely underground, where lightning is a small factor, and they are not interconnected to a great extent on account of the greater reliability of the low potential of the system. The breakers are not subject to such excess capacities, hence the low-potential breaker problem is not such a difficult one.

In addition to the above-mentioned system, we have the system which consists of large capacities covering an area of such size and such power density that high-voltage, high-capacity lines are necessary for transmission, and a medium voltage with high current values is necessary for primary distribution. Such systems are usually highly interconnected within themselves and also with neighboring systems, hence the switching is not only complicated but is subject to great concentration of capacity, and is subject to and very susceptible to lightning and disturbances which are particularly severe on the breaker, where the current's concentration is great and the potential high enough to make arc extinguishing difficult.

The experience of the operator with breakers depends on the system; how it is built and how operated. The more exacting the service, the more experience the operator gets with breakers. For instance, if the service is not exacting, breakers can be adjusted so they will not open until the intensity of the trouble reduces, and then a number of breakers can be allowed to function and greatly reduce the individual strain and probably cut off the power from a breaker in which the arc would re-establish with disastrous results if it remained energized. If service would allow breakers to rest a while after opening so the gas might escape and the oil settle the contacts, and the oil in their vicinity cool, the breaker would perform with less trouble. On the other hand, if the system supplies much service upon which life and property depend, the breaker cannot be nursed but must be sacrificed, if necessary, for the sake of service.

My experience has been with a system and breakers in the latter class, hence I will confine myself largely to the circuit-breaking problem of the West Penn System, and endeavor to give you practises and experience with that system from its conception to its present development. The West Penn System consists of five power stations having a capacity of 226,000 kv-a. connected by and serving the public over 215 mi. of 66-kv. circuits (122 mi. of which are constructed and fitted for 132 kv.,

Abridgment of paper presented at the Spring Convention, Birmingham, Ala., April 7-11, 1924. Complete paper available without charge to members on request.

and shortly will be operated as such); 1350 mi. of 25-kv. circuits (25-kv. also includes 22-kv.) and 661,000 kv-a. in high-voltage transformers, covering an area of 12,000 sq. mi. In addition, this system is interconnected with several other large systems, embracing the American Gas & Electric Company, Ohio Power Company, Northern Ohio Traction Company, Cleveland Illuminating Company and the Duquesne Light Company—who are connected with the Pennsylvania and Ohio Power Company, and the Harmony Electric Companies, making a total connected power station capacity of 1,092,000 kv-a., with 280 mi. of 132-kv. circuits; 850 mi. of 66-kv. circuits, 2370 mi. of 25-kv. circuits and 3,447,000 kv-a. in high-voltage transformers. Connections are now planned and rights-of-way partly secured, which will add to this group the systems of the Penn Public Service and the Potomac Edison, both of which are already connected with the Penn Central and the Keystone Power Corporation, connecting power station capacities of 1,280,000 kv-a. with 375 mi. of circuit above 100 kv., 937 mi. between 50 and 100 kv., 4200 mi. between 20 and 50 kv., and 3,865,000 kv-a. in high-voltage transformers.

With such systems connected as they are, you can understand that the switching problem of the West Penn System, with which these larger capacities are connected, is no mean undertaking.

In 1902 the West Penn System started with 6000 kw. 38.5 mi. of 22-kv. circuit and 10,000 kw. in transformers, using single-pole stick breakers. These breakers operated by a fuse melting, this releasing contact mounted on swinging arm which moved through a wide angle making a 72-in. break in air.

This type of breaker was fairly satisfactory for a time, but as the system grew in line and transformer capacity, trouble developed from the breakers only opening part of the phases, which resulted in insulation breakdowns from surges and the floating neutral which was not grounded, the transformers all being two-phase low and Scott three-phase high.

As a result of these limitations in 1906, when our transformer capacity had grown to 15,000 kv-a. and the transmission system consisted of 107 mi. of 22-kv. circuit, it was decided to discontinue the practise of installing stick breakers and place oil breakers in all of the new developments and some of the more important old ones. This breaker differed from the ordinary ones in that the top, bushings and tanks were made of wood fiber, and it had two additional tanks in which were located oil-insulated series transformers having three ratios. Inverse time-limit relays were mounted on the breaker beside the tripping coil. This breaker was a 300-ampere, 50-kv. test, and used for 22-kv. service, but at once proved it did not have sufficient capacity and gave trouble.

We then installed a 400-ampere breaker of the same make which also had top, tanks, posts and bushings of wood fiber, and tested to 125 kv. This breaker differed from the smaller breaker in that it had four breaks per pole with a series trip coil located between and connected with the center stationary contacts, which were supported by posts. This breaker was mounted and connected the same as the smaller breaker. The enclosure was similar except there were partitions between the poles. The manual control was the same but, in addition, some breakers were electrically operated.

At the same time the lightning arrester arrangement was changed and an arrester placed on each line to protect the breaker.

During the period from 1912 to 1920 these breakers were controlled by a very simple and effective system of impedance relays designed and built by ourselves, which locked all line breakers, making them non-automatic until the potential dropped in the zone where the breaker was located, to correspond with the setting of a low-voltage relay which unlocked the breakers and allowed them to operate from overload.

This breaker was universally used by us for all 22 and 25-kv. service from 1906 to 1920, except the breakers at the main power stations, where there were breakers of a different make having two breakers per pole greater carrying capacity, a lower electrical test and about the same rupturing capacity.

During this period, the system grew from 6000 kw. to 98,433 kw. installed, and from 107 mi. of 22-kv. circuits to 757 mi. of 25-kv. and 26 mi. of 66-kv. circuits; transformers connected from 15,000 to 161,343 kv-a. and the 25-kv. line insulators increased to a wet test of 90-kv.

All this, of course, increased the duty on the breakers, with the result that all breakers on the 25-kv. system had to be reinforced.

As the system grew and was fed from numerous points, the relays mentioned before proved inadequate. In order to provide current to operate modern relays, it was necessary to provide series transformers, which we built and placed on the breaker bushing.

These breakers, which originally would only break about 1200 amperes are still in use giving remarkable service in locations where the short-circuit current is limited to about 2500 amperes.

We have had considerable experience with many other breakers made by different manufacturers, which we inherited or that were placed on our system by our customers, or consulting engineers of our own. All of these breakers have given trouble when their capacity was approached, and it has been necessary to limit the capacity back of them by moving them to another location, or back them up by high-capacity breakers.

We have also found that circuit breakers require servicing and that a thorough system of servicing pays big dividends. This department, which we call our "Savings Department," comes under our relay engineering department, and is under the supervision of a very high grade relay and breaker expert. His organi-

zation consists of first class relay and breaker engineers and mechanics. They have available motor cars and equipment necessary to do all kinds of mechanical and electrical breaker servicing and have supervision over all relay and breaker installations before and after they are put in service.

In 1919, when a new station was started which would have an ultimate capacity of 30,000 kv-a. we took up with the breaker manufacturer the design of a higher-capacity breaker of the 25-kv. class, and as the result, contracted for a large number of breakers for both in- and out-door service, which would have a potential test of 140 kv., a current capacity of 600 amperes and a rupturing capacity of 16,000 amperes at 25 kv., under A. I. E. E. rules.

In January, 1923, it became apparent that we would need breakers of still greater capacity on our 25-kv. system. As our plans for connecting additional properties acquired and inter-connecting with other large utilities with high-voltage transmission made it possible to develop short-circuit current too great for the 16,000-ampere breakers, the matter was again studied and contract made for a large number of breakers, guaranteed to have a potential test of 140 kv., current capacity of 600 amperes and a rupturing capacity of 25,000 amperes at 25 kv.

The three 25-kv. breakers which will most generally be used on our system are the 2500, 16,000 and 25,000 ampere breakers. In the case of the middle size breaker the conduit runs are long and expensive as the relays are mounted in substation buildings, and in some cases buildings have to be erected to protect the relays, while with the larger breaker the relays can be placed in the operating mechanism box, which is made large to accomodate same and thus save the cost of the conduit run and relay housing. Therefore, the cost of the two larger breakers installed is about equal, even though the breakers are quite different.

In the case of the higher potential, we have followed the manufacturer's standard more closely, using 73-kv. breakers for 60 to 69-kv. service, and 135-kv. breakers for 120 to 132-kv. service, because practise has shown that these classes are not so affected by lightning disturbances.

All operators have had more or less trouble which originated in or outside of the breaker itself. These difficulties will again depend largely on the system of which the breaker is a part, where located and how operated. Let us first think of those troubles which originate in the breaker itself, and then those which originate from causes outside of the breaker, and try to suggest ways of correcting improper happenings.

The principal cause of trouble originating in the breaker itself is a reduction in the insulating value of the various insulating mediums, and that reduction is generally due to the presence of moisture. I have often been asked "how does the moisture get in?" and counter with "what keeps the moisture out, that stays out?" and as I could never find what keeps it out, will give you a few ways in which it gets in.

We pour it in with the oil, yes, even if the oil does test up very high, moisture is generally present in such small particles and so separated that it is not detected by the normal methods of testing but can be detected by some forms of heat tests. These moisture particles are collected on the surfaces of breaker members by the electro-magnetic field, which generally holds the moisture in the small globule form where it deposits until it is absorbed by insulating material or the breaker is de-energized, when the small globules combine and form large globules which descend by gravity and capillary attraction until they come in contact with insulating material which will absorb them, or descend through the oil to the bottom of the tank, if the oil does not have such an affinity for moisture that it will again absorb it, in which event the cycle repeats. This may be prevented by using an oil which has very little affinity for moisture and is free from moisture when placed in the breaker. But what about the moisture which accumulates in breakers from condensation or is taken in by the breaker breathing?

Breakers can and should be made moisture proof and provided with quick opening vents, which would relieve gases but prevent moisture from entering the breaker, and then the many failures which originate from moisture in breakers will be a thing of the past, providing proper oil is used.

Other causes of trouble originating in the breaker itself are the many mechanical weaknesses which develop, some from expansion and contraction, others from material deterioration, but generally due to the design, particularly the very sudden starts and stops which create excessive strain and shock, resulting in the failure of many parts and very faulty latch operation. We have had cases where we had to put on a latch to latch the latch, and others where the latches would latch, but on account of their having to be so sensitive, would often vibrate off.

When thinking of those troubles which originate from causes outside of the breaker, let us include breaker failures for which the breaker is solely responsible but which follow outside disturbances. The most common causes of such trouble are lightning, surges and over-capacity. The first two generally result in electrical breakdowns but there have been cases where breakers have been wrecked by lightning as if blown up from an explosion, when no electrical breakdown was apparent. Electrical failures generally happen to the bushing, although we do have electrical breakdowns from the contacts through the oil and lining to the tank, from those which take a path to ground via the insulator supporting the movable contact and also from the top of the bushing to the breaker mechanism, wrecking it and rendering the breaker inoperative. Bushing failures are usually the most disastrous of the electrical failures and if we only stop to consider a second the

duty expected of a breaker bushing, I am sure we would realize that breaker bushings should be more liberally designed and tested than any other bushing for like service, as the breaker bushing is frequently the end of a circuit where the electrical stresses build up very high, as there is no beyond over which the stresses may distribute or discharge, as is the case with bushings such as transformer, inlet and arrester bushings. The remedy for these troubles is more liberal insulation, which, it is true, may mean a larger breaker. "But how much more liberal?" I have been asked. That depends upon your system, its size, how the lines are insulated, how effective the arrester equipment and what kick it is possible to get when switching. More than a quarter of a century of experience has shown that the most satisfactory bushing for all kinds of service is one that is free of stresses caused by the method of support, takes its load under compression and has a loose insulated conductor fastened at one end only. Such a bushing is hardly feasible for extremely high potential and some types of outdoor equipment.

Over-capacity failures are the most disastrous. I have seen breakers that were completely demolished by explosions; others that were completely destroyed by the fire following an over-capacity explosion, and frequently great damage done to both indoor and outdoor substations. An over-capacity failure is any failure which results from a breaker susceptible to greater capacity than it can successfully interrupt, that is, the capacity may be in excess of that for which the breakers were designed, or may be considerably less, and the breaker capacity reduced even below such values by defective oil. I remember a case of oil carbonizing greatly as the result of a single-breaker operation. Under normal switching, the oil did not seem to deteriorate at all but if the breakers opened on a short circuit, the oil would carbonize to such an extent that its test of 30,000 volts would be reduced to less than 7000 volts, and if the breakers were put back in service without correcting the oil and were subject to a second short circuit it would result in a failure even though the short circuits were only a small fraction of the breaker capacity. This resulted in the necessity of changing oil after every short circuit before the breaker was put back in service.

Other oils vaporize, volatilize and decompose very readily and create gases which have a very low dielectric strength and are so inflammable that they ignite as soon as they come in contact and form certain mixtures with the air, or are ignited by arcs which are formed or maintained as the result of the low dielectric strength of such gases. I have seen breakers which had, apparently, functioned properly and opened the circuit but which were wrecked as the result of gas being ignited by an electrical breakdown outside of the switch, caused by the low dielectric value of the gas.

All oils, however, are not bad. Different oils will make a difference in the functioning of a breaker. The best oil, however, is far from being a perfect circuit-breaker fluid. The expression brings mirth, but let's laugh on and try to imagine some of the characteristics of a perfect circuit-breaker fluid.

A perfect circuit-breaker fluid should be non-vaporizing or non-volatilizing, non-inflammable and non-absorbent of moisture, yet have a specific gravity considerably less than water; be non-corrosive, non-poisonous, non-adhesive and not subject to capillary attraction, but be capable of high heat conductivity so that the heat might be transferred directly to the container without motion of the fluid. It should extinguish the arc at the first electrical zero and prevent it re-forming; should have a very high and permanent dielectric strength and low viscosity; should not change through a temperature range from 100 deg. minus to 900 deg. cent. Its dielectric strength should have a negative coefficient, when in contact with arcs, which would dampen out arcs as a resistor to reduce shock, then return to its original state.

With such a breaker fluid the circuit-breaker problem would be very much simplified, but since we do not have such a fluid and have to be content with oils of various grades, the best of which rapidly deteriorates in any of the present day breakers, let us consider what kind of a breaker should be provided to give good service with poor oil, as I feel that it will be infinitely easier to design and build a better breaker than it would be to always procure the better oil.

Looking at this whole situation broadly we must realize that the trouble is not with the breaker. The breaker is just what we make it. The real trouble is with us.

1. The operator has not determined his breaker needs.

2. The manufacturer has not fitted himself, by research work, to meet the operator's needs.

3. The operator and manufacturer have not co-operated to develop, operate and service breakers as they should.

These are the three cardinal points in the breaker problem. If we get into the matter conscientiously the job is done.

ELECTRICAL INSPECTION IN MINES

Serial 2541, "Electrical safety inspection; suggestions for mine-safety engineers," by L. C. Ilsley, electrical engineer, Department of the Interior, has just been issued by the Bureau of Mines. This paper is intended for State mining inspectors, safety engineers of mining companies, and others interested in electrical safety inspection in mines. It presents the important points that should be watched by inspectors, and briefly reviews the work of the Bureau of Mines in the testing of electrical apparatus or equipment to determine their permissibility for use in gaseous coal mines.

Hydroelectric Practises and Equipment of the South

O. G. THURLOW AND J. A. SIRNIT

Member, A. I. E. E.

Both of Alabama Power Co., Birmingham, Ala.

UNTIL a short time ago little thought was given to the hydroelectric possibilities in the South and still less was its economic value appreciated. Coal was cheap and easily obtainable. Consequently, power could be generated cheaper with coal than by water. It is, therefore, an everlasting tribute to those pioneers with vision and courage, who in the face of such adverse conditions ventured into developing water powers and laid the foundations for the great hydroelectric developments that we have today in the South.

Hydraulic Power Resources of the South

The rivers of the Southeastern section of the country and their tributaries, originating on the southern part of the Appalachian Highlands, not having the perpetual snows, depend solely upon the seasonal and periodical precipitation for maintaining their flow. The average annual precipitation, which is greater than in any other part of the United States, ranges between 40 in. and 80 in.

Although this region is for the most part heavily timbered, which tends to prevent sudden run-offs and equalize the river flows, the rivers are subject to high variations in flow. The daily hydrograph of the Coosa River at Lock 12 for the year 1922, illustrates clearly the fluctuations of the river, and is typical of most of the southern rivers. Some rivers have even a greater flow variation, as for example, the Tennessee River, which has a flow ranging from 7200 second ft. minimum to 430,000 second ft. maximum, recorded at Florence, Alabama.

The ratio of rainfall to the run-off has also almost as wide a variation as the river flow itself. It varies with the location and also with the amount of rainfall. While at the headwaters the ratio is 3:2 or better, in the lower foothills it varies from 4:1 to 2:1, the highest ratio prevailing in dry seasons or years, the lowest in wet periods.

The following table gives rainfall and run-off data on the Upper Coosa basin for different representative years:

Year	Rainfall Inches	Run-off Inches	Approximate Ratio
1904—dry	40	9.5	4:1
1906—wet	63	30	2:1
1912— "	63	30	2:1
1916—average	47	18	2½:1

Abridgement of paper presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924. Complete paper available without charge to members on request.

For the most part, these rivers yield only run-off river power with very little primary, but a large amount of secondary power when supplemented with steam power or power from storage reservoirs, can be utilized wholly or in part to good advantage. Practically every river on its headwaters or on its tributaries has one or more possibilities for developing storage reservoirs, a number of which has already been developed. The principal storage developments already in operation are those of the Southern Power Company on the headwaters of Catawba River with a storage capacity of 13,500,000,000 cu. ft. and Georgia Railway and Power Company on the Tallulah River, one at Burton with 5,280,000,000 cu. ft. and one at Mathis containing 1,369,000,000 cu. ft. of storage.

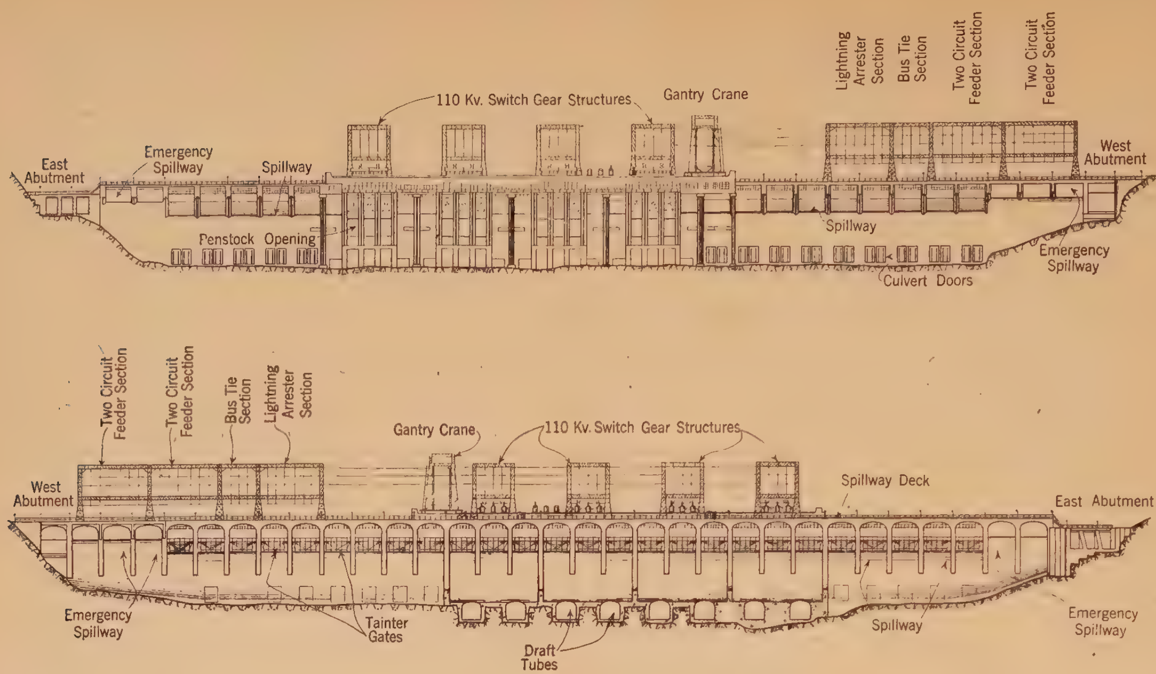
The Alabama Power Company has now in course of development a storage project on the Tallapoosa River at Cherokee Bluffs that will, when completed, have a storage capacity of 60,000,000,000 cu. ft. and will be able to develop approximately 136,000,000 kw-hr.

Design of Power Plants

The design of hydroelectric generating plants in the South does not differ materially from the design of similar plants elsewhere, and since practically all the developments are of recent date, with few exceptions, the plants are of modern design and construction. The generating units are of vertical type and in sizes ranging up to 30,000 horse power, depending on water-flow and head.

The majority of the southern hydroelectric plants are low-head developments with exception of the Tallulah Plant of the Georgia Railway and Power Company on the Tallulah River which has a head of 600 ft. and the Ocoee Plant of the Tennessee Power Company on the Ocoee River, with a head of 254 ft. These can be classed as medium high-head developments.

A departure from the conventional design of low-head power houses is represented in the Mitchell Dam Plant of the Alabama Power Company on the Coosa River. As it is well known, the run-of-river plant suffers an appreciable reduction of operating head during flood periods, and to overcome this disadvantage engineers have been forced to install a greater number of generating units where it was possible to do so, to compensate for the loss in capacity of each unit. Of course, such a procedure necessarily makes the installation more expensive with the resulting increase of production costs. In some instances provisions had to be made for admitting water into the draft tube through jets of relatively high velocity which, by acceleratig the velocity



Elevation of Dam and Powerhouse Looking Up-Stream

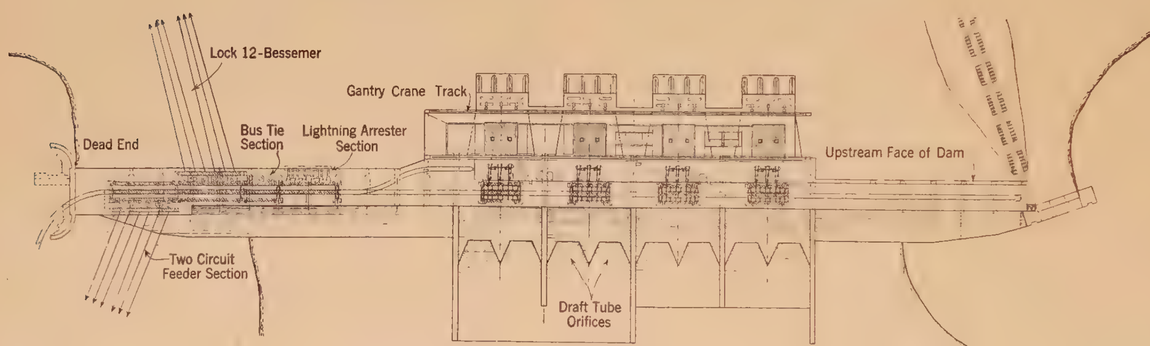


Fig. 1—26 Spillway Gates 30 ft. Wide by 15 ft. Deep—930 ft. Spillway, Including Piers

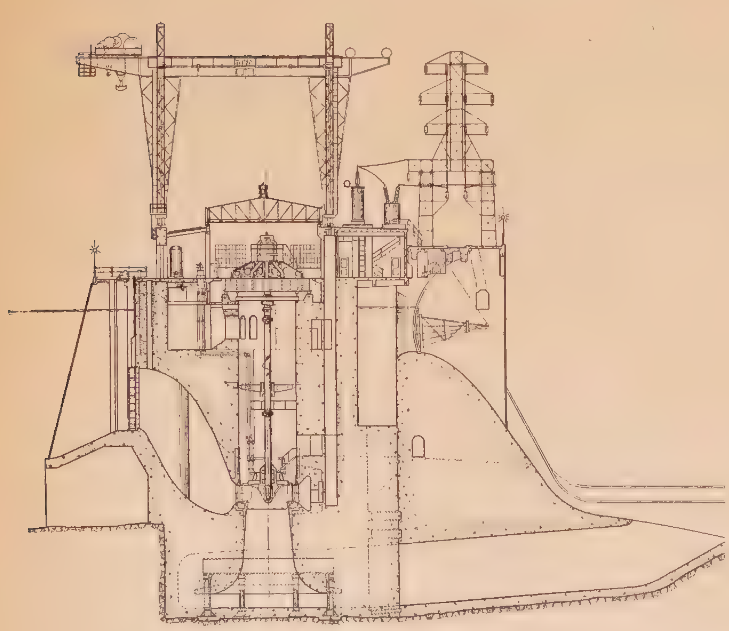


Fig. 1—Section

of the combined turbine discharge and jet water through the draft tube, produces a negative head.

In designing Mitchell Dam Plant, the idea was conceived that the most effective way to maintain the normal head on the waterwheel, and thereby the full capacity of the unit during flood periods, would be to remove the excess tail-water head from the discharge opening. This resulted in the development of what is now known as the Thurlow back-water suppressor. The introduction of this feature called for an entire change in the general design of the power plant, causing a departure from the established conventional practise.

The principal and most outstanding feature in this plant is the location of the power units on separate foundations in the river on the upstream side of the dam. (See Fig. 1.)

The usual power house building is entirely eliminated. The generator room is covered by a low movable roof, which is designed in two sections, joined on the transverse line and mounted on wheels; each section moving in opposite direction. In normal operation the genera-

tor room is completely enclosed, but for handling large parts of machinery, this roof can be opened and a gantry crane utilized for performing the necessary work.

The entire operating floor is on one floor level. The generators, governors, switchboard, low-tension switching, bus galleries and offices are easily reached without climbing stairs or ladders. This materially adds to the convenience of operators and makes supervision and inspection of the plant and its machinery more effective.

An elevator is also provided with each unit for use of the attendants in inspection of the turbine bearings and main shaft.

This power house is designed for operation on the unit system, that is, each generator and its bank of step-up transformers are connected as a unit. There is, however, also a transfer bus provided which enables parallel operation of all or any number of units and from which the station service power and lighting are obtained.

Southern Super-Power System

Comparatively little has been mentioned in print about the inter-connected system of the Southeastern States, yet it comprises one of the largest systems in the United States.

While the proposed Eastern super-power zone is still under discussion, a virtual super-power system has been in existence in the South for several years covering the States of Alabama, Georgia, Tennessee, North and South Carolina. The Southern zone consists of the inter-connected system of seven independent companies as follows:

Alabama Power Company
Columbus Power Company
Georgia Railway and Power Company
Central Georgia Power Company
Tennessee Power Company
Southern Power Company
Carolina Power and Light Company

A map of the Southeastern States showing the territory covered by these systems is shown in Fig. 2. It will be noted that the inter-connected system forms a complete network over a territory approximately 600 mi. long, and 300 mi. wide at its greatest width.

All large plants, hydro and steam, are connected to this system with an aggregate capacity of about 1,100,900 kw.

The main trunk-line is over 800 mi. long with several thousand miles of branch lines connected to it.

The inter-connection of these systems was accomplished by the building of tie lines and the installation of sufficient transformer and switching capacity at the tie-in points, to take care of the exchanged energy. Few changes had to be made in the individual systems themselves, as fortunately, all the companies involved had already standardized on a frequency of 60 cycles and most of them operated their principal transmission lines at 110,000 volts.

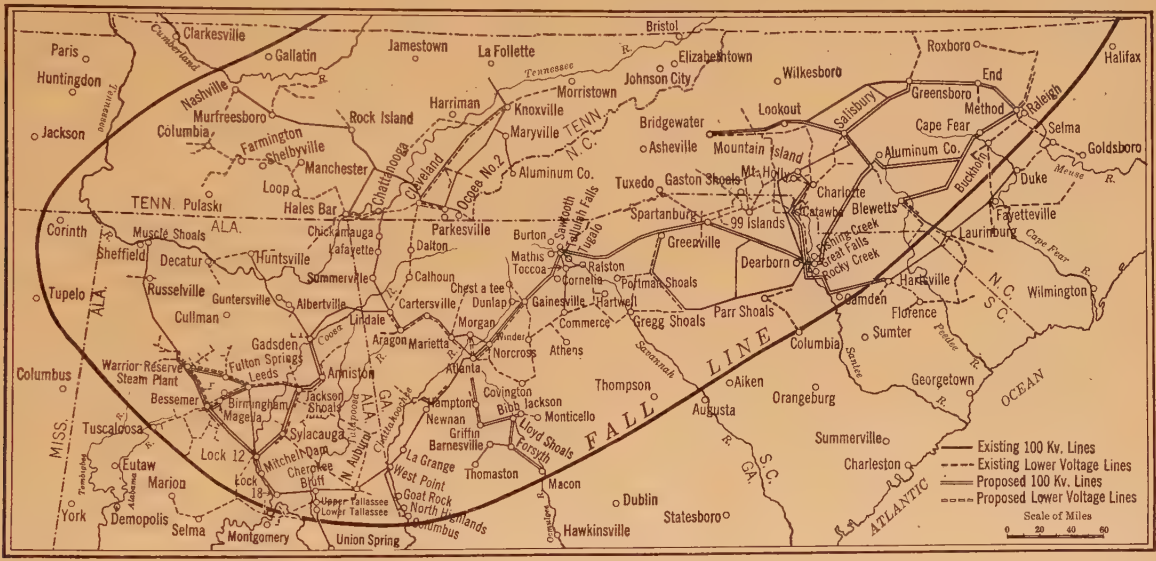


Fig. 2

Although energy has been transmitted a distance of about 600 miles on this inter-connected system, the use of high-voltage trunk-lines of the order of 220,000 volts has not been found necessary. It is obvious, of course, that no great bulk of power could be directly transmitted a distance of 800 mi. at 110,000 volts, but by a process of relaying the energy from generating stations to adjacent load centers, the same benefits have been accomplished. For instance, assume that the Carolina Power & Light Company at the extreme Northeastern end of the inter-connected system desires to secure a block of power which is to be supplied by the Alabama Power Company. The latter company delivers the required amount of power to the Georgia

Railway and Power Company at the Georgia-Alabama State Line, which will be absorbed on the Georgia system in that vicinity. The Georgia Railway and Power Company will then transmit energy from its Tallulah Falls Plant, at the other extreme end of its system, to the Southern Power Company. This Company will in turn absorb this energy locally and transmit a like amount from generating stations in the vicinity of the tie point of the Carolina Power and Light Company. The systems, relaying the energy, of course, deduct an amount sufficient to cover transmission losses, costs of transmission, etc.

During the Fall of 1921 several of the Southeastern power companies, recognizing the possibilities accruing from the inter-connection of the systems and anticipating a power shortage during the dry weather seasons, arranged to secure the use of the then idle steam plan at Muscle Shoals, Alabama. Accordingly, the Alabama Power Company leased this plant from the United States Government, and that Company in turn contracted with several of the other companies to hold in

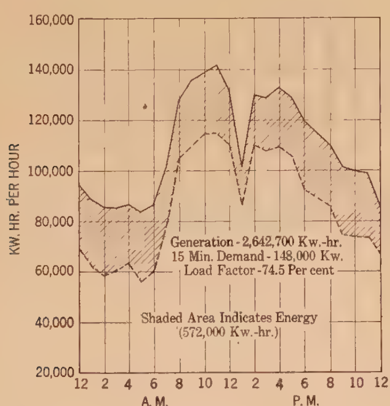


Fig. 3

reserve a certain capacity which could be used by these companies at any time upon reasonable demand.

The Muscle Shoals steam plant is located in the extreme northwestern section of Alabama, and connects with the Alabama Power Company's system through a 90-mi., 110,000-volt, single-circuit, transmission line at the Warrior River steam plant.

The value and importance of this arrangement and of the inter-connection were clearly demonstrated in 1922, when during an abnormally dry season in the Southeastern section, relief was given to companies in the Carolinas and Georgia. Some of the companies would have had to curtail power to their customers, had they not been able to secure this standby power. A typical load curve when power was being delivered from Alabama to the Georgia companies and the Carolinas for 24 hours of the day is shown in Fig. 3 where the unshaded area indicates normal system load on the Alabama Power Company's system, and the shaded area the energy delivered to other systems. For comparison, a typical system load curve of the Alabama Power Company's system for a day when no interchange of energy took place is shown in Fig. 4.

During certain seasons of the year it is possible to co-ordinate the operation of the Georgia and the Alabama Plants to secure maximum efficiency on each system. For instance, during the season when there is a surplus of water in the run-of-river plants, and when water is being stored at the reservoir plants, power is supplied from the Alabama system to the Georgia

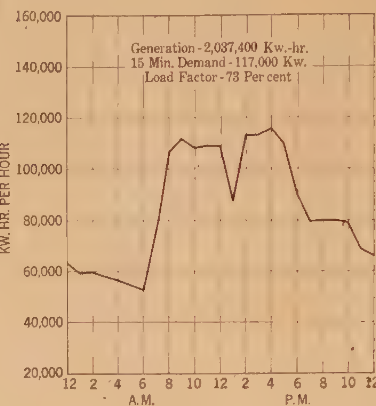


Fig. 4

system during the off-peak hours—the normal load on the Alabama system during off-peak hours being considerably less than the capacity of its hydro plants. This interchange, therefore, permits the operation of the flow of river plants at a very high load factor and conserves water at storage plants.

During the peak load hours it, of course, becomes necessary for each system to carry its own load and the storage plant draws down a certain amount of its

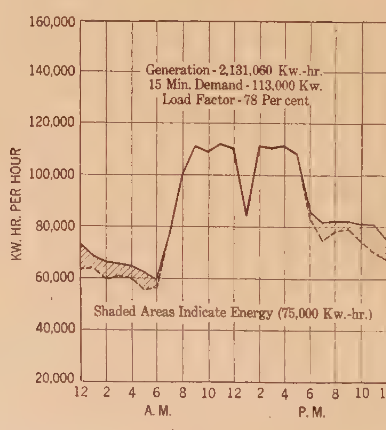


Fig. 5

stored water. A typical load curve on the Alabama Power Company's system when supplying off-peak power to Georgia is shown in Fig. 5. By referring to Fig. 4 it will be noted that considerable improvement is made in the load factor on the Alabama Power Company's system. Another method of operation which has proven of advantage is that of supplying energy from the storage plants to the Alabama systems during peak hours, and during the off-peak hours power is

returned from the Alabama system to the Georgia system. This reduces steam plant operation and permits the operation of run of river plants at high load factor.

Load dispatching on the inter-connected system is quite a simple matter, the principal requirements being close co-operation between dispatchers of the various systems, and sensitive governors in the main generating plants.

This inter-connection has also proved of advantage in increasing the reliability of service. Line or apparatus failures upon isolated systems naturally cause interruptions to customers. Upon inter-connected systems it is nearly always possible for the combined generating capacity to take care of any reasonable number of failures. This possibility has been well demonstrated by the use of the tie between Georgia and Alabama in emergency cases. In 1923 a severe sleet storm in northwest Georgia broke down some of the lines west of Atlanta, and the load in western Georgia was immediately picked up and carried from the Alabama Power Company's system until repairs could be made. Likewise interruptions to customers in Alabama have been prevented by use of the tie-line.

As the load on power systems continues to increase, the benefits of inter-connection will become more and more pronounced. To summarize, some of these benefits are as follows:

1. Reliability of service.
2. Reduction of total reserve capacity.
3. Economies due to diversity of stream flow in different water sheds.
4. Economies due to diversity of load factors.

Surface Iron Losses With Reference to Laminated Materials

BY T. SPOONER
Member, A. I. E. E.

and

I. F. KINNARD
Associate, A. I. E. E.

Both of the Westinghouse Electric & Mfg. Co.

Review of the Subject.—*Surfaces or pole-face losses are assumed to be governed by ten factors and the influence of each on the resulting losses is considered. After reviewing the work of the previous investigators an account is given of some rather extensive tests recently completed by the writers. These tests cover results obtained on an experimental salient pole machine and an experimental 3-phase induction motor. Data are given for various types and thicknesses of commercial sheet.*

For a given material and machine the surface losses are assumed to be a function of the air-gap induction, ratio of slot width to single air gap, tooth frequency and slot pitch or width. The laws of variation of surface losses with respect to these variables are determined from experimental results and are shown to be in general exponential. The relation between hysteresis and eddy-current losses and the effect of variations in thickness and resistivity of laminations is considered in some detail.

Simple methods are given for applying these results to actual design problems which involve plotting the various functions on double log paper, a slide rule being then sufficient for all calculations.

The appendix gives a description of a graphical method of separating the various types of core losses which exist in a polyphase induction motor.

SURFACE losses, or pole-face losses as they are sometimes called, are common to nearly all types of rotating machines in which at least one member is slotted. In many machines they are responsible for a very appreciable percentage of the total no-load losses. It is often very desirable to be able to calculate their magnitude with a reasonable degree of accuracy and it is sometimes well to know the best way in which to reduce them.

It is the purpose of this paper to analyze as accurately as possible from the data which we have available the various factors affecting surface losses and to combine them into easily usable design formulas.

We shall define surface losses as those hysteresis and eddy-current losses which occur just below the surface of a magnetized smooth-core laminated material which is adjacent to a slotted member having a relative motion with respect to the first member. One of the most familiar examples of pure surface losses is in the poles of salient-pole machines having no damper windings. When this first member is slotted as well as the second the losses of the former are increased due to the greater penetration of the pulsating flux and to the higher flux density. The losses due to high-frequency pulsations penetrating through the whole length of a tooth will be known as tooth-pulsation losses. A discussion of this latter type of loss is beyond the scope of this paper.

Factors Affecting Losses

In analyzing this problem we wish especially to acknowledge our debt to Adams and his collaborators for the aid received from their classic paper on "Pole Face Losses."[1] In considering this problem we have taken into account the following factors:

1. Air gap induction B_{AG}
2. Field form
3. Ratio of slot width to single air gap q

Abridgment of paper presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., Feb. 4-8, 1924. Complete copies to members on request.

1. Adams, Lanier, Pope, Schooley. TRANS. A. I. E. E., page 1133 (1909).

4. Tooth frequency f_t
5. Tooth pitch λ or slot width σ
6. Resistivity of material ρ
7. Thickness of individual laminations t
8. Hysteresis coefficient η.
9. Insulation between laminations
10. Effect of punching.

Surface losses are a function of the flux density, the frequency of pulsation and the quantity of material involved as is the case for the simpler problem of the alternating-current transformer. The additional complications are due to four things: (1) the very appreciable departure of the pulsating wave form from that of a sine wave; (2) the rapid decrease in the amplitude of pulsations from the surface inward; (3) the fact that the high-frequency pulsating fluxes are superimposed on the fundamental-frequency flux variations (namely, we have a case of displaced unsymmetrical hysteresis loops which produce increased hysteresis losses over those caused by symmetrical hysteresis loops of the same amplitude of pulsation); (4) due to the high frequency of the tooth pulsations and to the thickness of material commonly used, skin effects become quite appreciable.

We have two general types of field form, *i. e.*, the flat top as given by a salient-pole machine with uniform air gap and the sine as usually approximated in the induction motor. With chamfered poles we may have almost any form in between.

The flux density is determined chiefly by the average air-gap induction B_{AG}. Of course for a sine-wave flux distribution the maximum flux density is greater than for a flat top distribution for the same average air-gap induction. The frequency f_t or number of minor hysteresis loops is determined by the number of teeth which pass a given position per second. The magnitude of the flux pulsations in the air gap is chiefly determined by the ratio of slot width to radial air gap (equals q). The depth of penetration of the pulsating fluxes is chiefly a function of the slot pitch λ or perhaps more accurately the slot width σ.

In other words, the first five items of the factors affecting losses give us a measure of the three fundamental variables, induction, frequency and volume of material as previously outlined.

In considering the quality of the material which for the transformer is determined by the Epstein or some similar test we must consider items 6, 7 and 8. The sixth item, resistivity of the material ρ determines, together with item 7, the thickness of laminations t, the eddy-current loss to be expected, assuming perfect insulation between laminations. It must be remembered that these two factors also govern the skin effect as produced by the screening currents of Mr. Adams' previously-mentioned paper. These effects can by no means be neglected for commercial laminated poles. Item 8, the hysteresis coefficient governs the hysteresis loss. This in turn is affected by the screening currents and by the amplitude of the displacement of the minor high-frequency hysteresis loops from the normal position.[2,3,4] Items 9 and 10, the insulation between laminations and the effect of punching, are incidental to the process of manufacture and will be considered in detail later.

Scope of Experimental Work

Our experimental work was divided into two parts; (1) pole-face losses for salient pole machines; (2) surface losses for induction motors. The salient-pole losses were obtained on a special four-pole railway motor supplied with various sets of poles of different materials so arranged that the air gap could be varied at will. The induction-motor losses were obtained on a special induction motor provided with an open-slot stator and several rotors of the same material, but having different diameters.

Test Apparatus

Railway Motors. The salient pole machine was mounted on ball bearings and direct-connected by a flexible coupling to a small variable speed d-c. motor. The latter had ordinary sleeve bearings. Two armatures were provided for the railway motor having the following general dimensions.

TABLE A

	Armature A	Armature B
Diameter	9 in.	9 in.
Length	7 in.	7 in.
Number of slots (open)	31	60
Slot width at air gap	0.370 in.	0.220 in.
Slot pitch at air gap	0.911 in.	0.471 in.
Slot depth	1.184 in.	0.8 in.

Neither armature had any vent ducts but armature *A* had three 5/8-in. band-wire slots 1/16 in. deep. Armature *B* was smooth. There were no windings on the armatures except certain exploring coils to be mentioned later. Several sets of poles were constructed for this machine made of the following materials.

0.125-in. Bessemer unenameled
0.0625-in. " enameled
0.0281-in. " unenameled
0.0281-in. " enameled
0.0172-in. 0.9 per cent silicon unenameled
0.0172-in. 0.9 per cent " enameled

These poles were shortened so that an adjustment of 1/2 in. could be made in the air gap by means of shims. The pole dimensions are given by Fig. 4.

Induction Motor. The induction-motor set con-

2. The Effect of Displaced Magnetic Pulsations on the Hysteresis Loss of Sheet Steel. L. W. Chubb and Thos. Spooner, Trans. A. I. E. E. (1915) page 2671.
3. The Unsymmetrical Hysteresis Loop, John D. Ball. Trans. A. I. E. E. (1915) page 2693.
4. Tooth Frequency Losses in Rotating Machines, Thos. Spooner, A. I. E. E. Journal 1921, page 751.

sisted of a special ball-bearing induction motor direct-connected to a ball-bearing, adjustable-speed, d-c. motor. The latter was arranged to be driven by means of a storage battery. The general dimensions are as follows:

TABLE B

Stator punchings........O. D. = 19 in.	I. D. = 14 in.	
Length................	= 6 in.	
Number of slots (open)..	= 60 in.	
Slot width at air gap....	= 0.346 in.	
Slot pitch at air gap.....	= 0.711 in.	
Slot depth.............	= 1.6 in.	

Rotor Punchings

Diameter rotor No. 1 = 13 17/32 in.	Single air gap (mils)	= 31.5
" " No. 2 = 13 1/2 in.	" " " "	= 47
" " No. 3 = 13 7/16 in.	" " " "	= 78
" " No. 4 = 13 3/8 in.	" " " "	= 109.5
" " No. 5 = 13 1/4 in.	" " " "	= 172

The stator and rotor punchings were made of enameled 0.0172, 0.9 per cent silicon sheet steel. All of the punchings were obtained from the same lot of steel. Special pains were taken to remove the burs from the punchings before enameling. The three-phase stator windings were arranged in 12 sections and could be connected for 110, 220 and 440 volts, 60 cycles and 4 poles. Fractional-pitch windings were used so as to give an approximate sine-wave distribution of flux. The rotors were supplied with a few small longitudinal slots in the surface 1/16 in. square. Suitable exploring coils were placed in these slots and brought out to slip rings.

Methods of Test

Salient Pole Machine. The method of test consisted in placing a set of poles in the machine obtaining the friction and windage losses with no field current and then gradually increasing the field current and noting the increased input to the d-c. drive motor. These tests were repeated for various speeds and air gaps. By extrapolating the curves between loss and air gap to infinity air gap the magnitude of the pole-face losses was estimated. This was done for each set of poles as noted above.

Induction Motor. Two methods of test were used for determining the induction motor losses.

1. Three-phase alternating current was applied to the stator, the rotor driven at various speeds below and above synchronism and the a-c. and d-c. inputs noted.

2. Direct current of a certain value was applied to one phase of the stator with one-half this current reversed in the other two phases. The rotor was then driven by the d-c. motor and the input to this motor noted for various speeds and stator excitations.

In order to separate the various losses of method 1 (a-c. applied to the stator) an approximate method was developed as follows: A definite three-phase voltage was applied to the stator and the rotor revolved at various speeds below and above synchronism. The a-c. and d-c. inputs were noted, the results corrected for friction, windage, $I^2 R$ losses, etc. and then plotted. From the characteristics of the resulting curves plotted between input and rotor speed, the fundamental-frequency stator and rotor iron losses could be calculated and subtracted from the total input, thus leaving the surface losses. This method is described in detail in the Appendix of the complete paper.

For method 2, (d-c. excitation) we have present no stator losses but only the rotor losses. After subtracting the friction and windage losses in the d-c. drive motor, the remaining losses as determined at 600, 1200 and 1800 rev. per min. for the five rotors having different diameters were plotted against air gap and the results extrapolated to infinity air gap. Assuming that the fundamental-frequency losses for all of the rotors were identical, the difference between these extrapolated values and the total rotor losses equalled the tooth-pulsation losses.

Test Results

Salient Pole Machine. After obtaining the pole-face loss results by the method outlined above the losses were plotted on double-log paper against each of the four variables B_{AG}, f_t, q and λ, where

B_{AG} = air gap induction,
f_t = tooth frequency,
q = ratio of slot width to air gap,
λ = tooth pitch.

From the average slope of the curves the mean exponent for each variable was determined. In general, these functions gave approximately straight lines, indicating that the variations were truly exponential except for the values of q. As will be noted later the ratio of variation of q varies; decreasing as q increases. Of course, these various functions are not altogether independent of each other but for a first approximation they may be considered to be so. In fact, the dependence of one function upon another is surprisingly small. It is obviously impossible to reproduce even a small part of these curves here but the exponential values may be summarized as follows:

TABLE C

Exponents

Material	B_{AG}	f_t	q	λ
0.0172 M. A.............	2.2	1.7	1.7	1.1
0.0281 Bessemer.........	2.4	1.6	2.15	1.3
0.0625 "	2.6	1.6	2.2	1.3
0.125 "	3.1	1.6	2.3	1.3

Range of variables: B_{AG} = 25-60 kilolines per sq. in.
f_t = 600-1800 cycles
q = 2.2-4.1
λ = 0.471-0.911 inches.

From this information we may therefore write the surface loss equation for 0.0625 Bessemer, for instance, as follows:

$$W_s = K \times B_{ag}^{2.6} f_t^{1.6} q^{2.2} \lambda^{1.3} \quad (7)$$

This is quite similar to the formulas used by Adams.

Such an equation will give a good estimate of pole-face losses over a considerable range of the several variables, but it is not in convenient form to use.

Derived Design Curves. We therefore suggest that the variables be plotted on double-log paper, thus greatly facilitating their use. For instance, see Fig. 7. In order to draw such a set of curves let us assume that the surface loss for the following conditions equals 1.2 watts per sq. in. of the surface:

B_{AG} = 49.5 kilolines per sq. in.
f_t = 500 cycles per second
q = 2.85
λ = 1.17

Now place a point at an ordinate of 1 and an abscissa of 49.5 and draw a straight line having a slope of 2.6. This gives the B_{AG} function. Similarly place a point at an ordinate of 1 and an abscissa, say, of 500 and draw a line having a slope of 1.6. This gives the frequency function. Similarly the q and λ functions may be

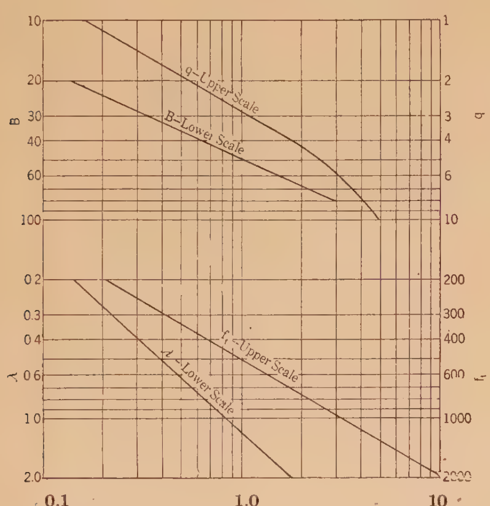


FIG. 1—SURFACE-LOSS CALCULATION CURVES FOR 0.0172 IN., 0.9 PER CENT SILICON STEEL
$W_s = 0.20\ K_{BAG} \times K_{f_t} \times K_\lambda \times K_q$

drawn. Finally the known loss of 1.2 watts per sq. in. give the constant of the equation and we have

$$W_s = 1.2 \times K_{B_{AG}} \times K_f \times K_q \times K_\lambda, \qquad (8)$$

where the K factors signify the respective ordinates for any desired value of B_{AG}, f_t, q and λ as read from the curves.

If desired the constant 1.2 may be eliminated by placing the reference point for one of the curves at an ordinate of 1.2 instead of 1. Similarly if the curves do not fit well on the sheet or overlap they may be shifted up or down at will and the constants changed accordingly. Or if one curve is shifted up and another shifted down an equal amount, no change in the constant need to be made.

Figs. 1-4 give the calculation curves for 0.0172 0.9 per cent silicon sheet, 0.0281, 0.625 and 0.125 Bessemer sheet steel, respectively. These are all placed on the same basis so that for the reference conditions the constant of each equation is proportional to the actual surface losses for each class of material.

It will be noted that the q curves go to much higher values than were covered by the test results. These curves were extrapolated from the induction-motor data and from test data by other observers. It is obvious

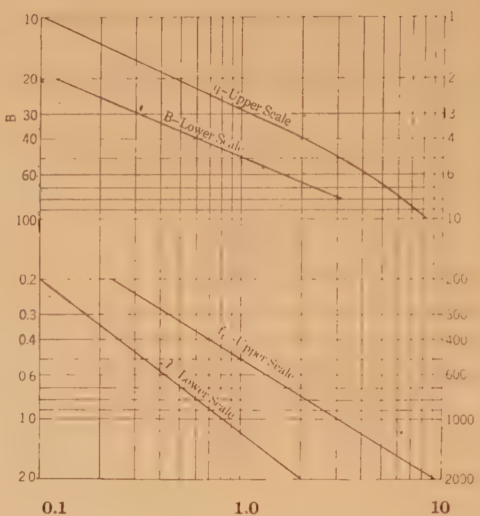


FIG. 2—SURFACE-LOSS CALCULATION CURVES FOR 0.0281-IN. BESSEMER STEEL
$W_s = 0.56\ K_{BAG} \times K_{f_t} \times K_\lambda \times K_q$

that q can not have a constant exponent since as the air gap approaches zero, q approaches infinity while the pole-face losses approach a constant value. Therefore the exponent of q would actually begin to decrease if q were taken sufficiently large. We believe that the

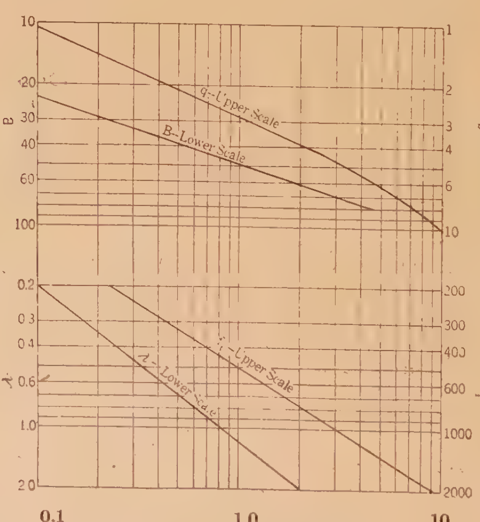


FIG. 3—SURFACE-LOSS CALCULATION CURVES FOR 0.0625-IN. BESSEMER STEEL
$W_s = 1.2\ K_{BAG} \times K_{f_t} \times K_\lambda \times K_q$

curves as shown are a very fair estimate of the way in which the pole-face losses actually vary with q.

Separation of Hysteresis and Eddy-Current Losses. It is obvious that if we wish to estimate the effect of changes in the magnetic quality of the materials enter-

ing into our poles, it is necessary to know the relation between the hysteresis and eddy-current components. In order to make an estimate of the relative values of these two components the pole-face losses for a given set of poles were reduced to watts·cycle and the results plotted against frequency. The intercepts on the vertical axis give a measure of the hysteresis components. The skin effect causes the hysteresis losses to increase somewhat faster than the first power of the frequency and the eddy-current losses to increase somewhat more slowly than the square of the frequency.

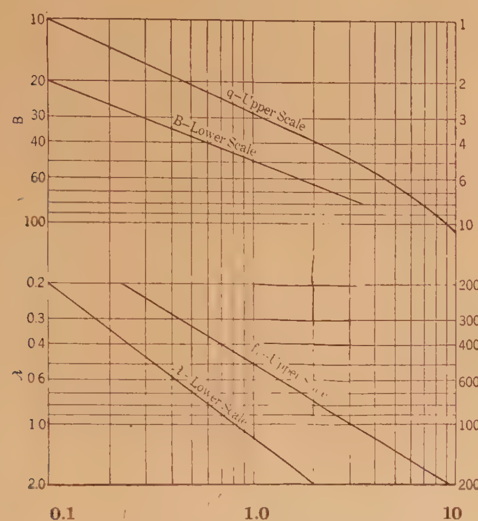


FIG. 4—SURFACE-LOSS CALCULATION CURVES FOR 0.125-IN. BESSEMER STEEL

$W_s = 2.6\ K_{BAG} \times K_{f_t} \times K_\lambda \times K_q$

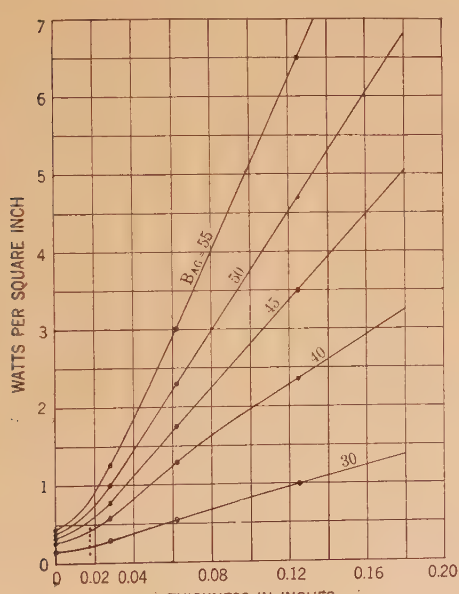


FIG. 5—RELATION BETWEEN SURFACE LOSSES AND THICKNESS OF LAMINATIONS FOR BESSEMER STEEL

$f_t = 620 \sim$
$q = 3.7$ in.
$\lambda = 0.912$ in.

Effect of Gage. In order to study the effect of gage, Fig. 5 has been plotted. This shows the relation between surface losses and thickness of individual laminations for various gages of Bessemer sheet steel and for various air-gap inductions. It should be noted that for quite thick material the rate of increase of pole-face losses with gage is approximately equal to the first power, while for thin gage material the rate of increase is approximately as the square of the thickness of the individual laminations. The vertical row of dots at a gage of 0.017 is for 0.0172 0.9 per cent silicon sheet steel. It will be noted that the 0.9 per cent silicon losses fall far below the Bessemer loss curves. This thin sheet has a considerably higher resistivity and considerably lower hysteresis loss than Bessemer steel which accounts for these differences.

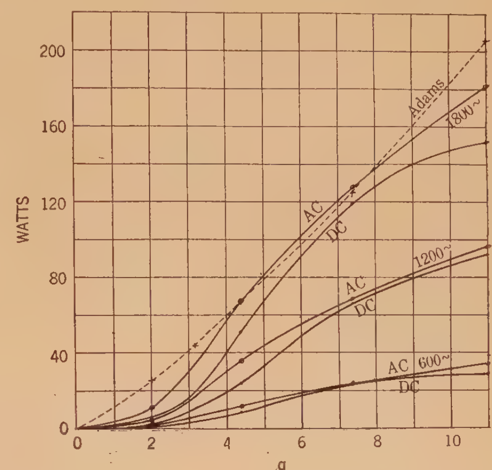


FIG. 6—COMPARISON OF INDUCTION-MOTOR SURFACE LOSSES WITH DIRECT CURRENT AND ALTERNATING-CURRENT STATOR EXCITATION AND WITH ADAMS FORMULA

$B_{AG} = 16$ kilolines per sq. in.

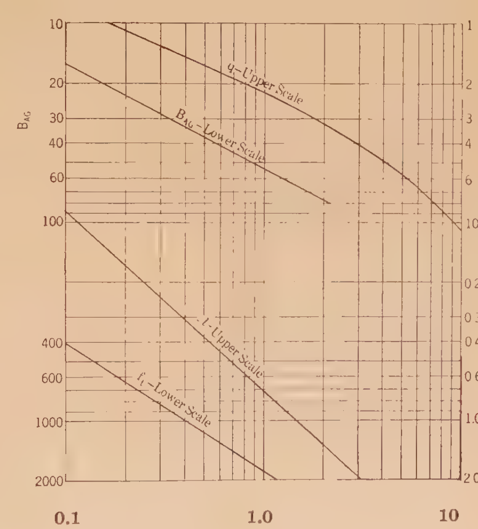


FIG. 7—INDUCTION-MOTOR SURFACE-LOSS CALCULATION CURVES FOR 0.0172-IN., 0.9 PER CENT STEEL

$W_s = 0.69\ K_{BAG} \times K_{f_t} \times K_\lambda \times K_q$

Induction Motors. The method of handling the surface-loss test results as obtained by the test procedure

outlined above was the same as for the salient-pole-machine data. The four functions B_{AG}, f_t, q and λ were plotted on double-log paper against surface losses and the average exponents determined with the following results for 0.0172 0.9 per cent silicon sheet steel.

TABLE E

Function	Test Range	Exponent
B_{AG}	4-40	1.9
f_t	100-2700	1.55
q	2.01-11	2.3-0.93
λ	0.711	1.1 (assumed)

Fig. 6 gives a comparison between surface losses plotted against q as obtained by the a-c. and d-c. methods of test. There is also included a curve as calculated by Adams formula for 0.014 material.

Fig. 7 gives a calculation curve for surface losses for 0.0172 material under induction-motor conditions, namely, a sine-wave space distribution of flux.

Summary

An attempt has been made to separate the various factors which govern the surface or pole-face losses of laminated material in rotating machines and to determine the way in which these losses vary with each factor. By a separation of the hysteresis and eddy-current components it has been shown that while the eddy losses are responsible for the larger part of the surface losses the hysteresis losses are very appreciable and can not be neglected. As a basis for this analysis test results were obtained on a salient pole machine supplied with various sets of poles arranged for variable air gap and on a special three-phase induction motor supplied with a number of smooth-core rotors having slightly different diameters. The rotors of the two machines contained no windings except exploring coils and were direct-connected to d-c. drive motors, the input to which gave the losses for the various conditions of test. By a suitable separation of the fundamental-frequency losses from the total losses the surface losses were given. This was done either by varying the air gap and extrapolating to infinity air gap (zero surface losses) or by a special method for the induction motor described in detail in the Appendix of the complete paper.

The surface losses were assumed to be a function of four main approximately independent variables, namely air-gap induction B_{AG}, tooth frequency f_t, ratio of slot width to air gap q and the slot pitch λ. These losses are approximately an exponential function of B_{AG}, f_t and λ but the ratio of variation of losses with q decreases as q increases. As a rough approximation the surface losses vary as the square of the air-gap induction, as the 1.5 power of tooth frequency, from the second to the first power of q with increase in q, and as the first power of the slot pitch. These losses can most readily be represented as a function of these variables by plotting on double-log paper, three of the functions being straight lines. Knowing these four variables which the designer can determine very readily the surface losses can be calculated in a few moments by a simple multiplication on a slide rule. This avoids the use of logarithms in spite of the fact that the functions are exponential.

It is shown that by plotting the surface losses in watts/cycle against frequency it is possible to obtain an approximate separation of the hysteresis and eddy components. The hysteresis loss at 1000 cycles is about 30 per cent of the total surface losses for all the materials investigated. Due to the skin effect this separation may be somewhat inaccurate since the hysteresis loss increases faster than the first power of the frequency and the eddy loss less rapidly than the square of the frequency. Due to the uncertainty as to the effective permeability it is impossible to accurately calculate this skin effect. The net result of skin effect is decreased losses since the decrease in eddy losses is considerably greater than the increase in hysteresis losses. Due to the fact that the high-frequency pulsation hysteresis loops are usually greatly displaced from the normal symmetrical position, the hysteresis losses are much higher than would be the case for symmetrical loops for the same frequency and amplitude.

In addition then to the four factors B_{AG}, f_t, q and λ which govern surface losses for any given material and are a function of the design of the apparatus we have the four fundamental factors: Hysteresis coefficient η resistivity ρ, thickness of individual laminations t and the effective permeability μ which are determined by the nature of the laminated material. The factor η governs not only the hysteresis loss but according to Latour's formulas when skin effect is appreciable also affects the eddy losses somewhat. The eddy losses are inversely proportional to ρ for small frequencies but for high frequencies are inversely proportional to the square root of ρ. Also the eddy losses are proportional to the square of t for low frequencies and thin material and to the first power of t for high frequencies or thick material. With a given flux density for low frequencies μ is not a factor, but for high frequencies the eddy losses are inversely proportional to the square root of μ and the hysteresis losses directly to the square root of μ. The permeability also influences the attenuation of the pulsating flux but we have no data in regard to this factor and it is probably not very different for the different classes of commercial materials.

It is shown that for chamfered poles approximately correct results may be obtained by assuming that the air gap is that corresponding to the minimum gap. The change in field form largely compensates for the increased gaps at the tips of the poles.

Enamel on the individual laminations of salient poles only slightly decreases the surface losses although it may materially affect the relative hysteresis and eddy losses. In most cases it is an extra manufacturing expense which would be unwarranted.

Due to the hardening of the material near the edges

caused by punching the hysteresis surface losses are undoubtedly increased unless the punchings are subsequently annealed. We have no specific data in regard to this effect with reference to surface losses but would expect an increase in hysteresis losses due to punching of from 5 to 10 per cent.

It is believed that the surface-loss curves here presented may be used with considerable confidence at least for open slots where the slot and tooth widths are approximately equal. Our results check those of Adams and his collaborators with a reasonable degree of accuracy although they used different methods of test. Again our results for the salient pole machine and for the induction motor check very well with each other although the methods of test and the conditions for the two types of machines were quite different. In other words we believe that our curves are based on all of the important fundamental factors which govern surface losses. Finally, the check results which we have on commercial machines show a fair average check although some of the individual machines show considerable discrepancy between calculated and test results. This we believe, however, is due largely to inaccuracies in the commercial testing rather than in the formulas.

From the calculation curves given we believe it is possible to predict from the fundamental characteristics of a new material, namely, η, ρ, t and μ, the surface losses to be expected under any normal conditions of use. Even a simple Epstein test under standard conditions should give sufficient data for an approximate estimate for the surface loss constant.

It is hoped that this paper will bring out further test data on surface losses in order that a more accurate check on existing formulas may be obtained so that this type of loss may be calculated with the same degree of accuracy and confidence with which we now calculate transformer losses.

The Application of Automatic Control to Mine Substations

BY CARL E. H. von SOTHEN
Associate, A. I. E. E.
General Electric Company, Schenectady, N. Y.

Review of the Subject.—*The paper discusses the various methods of meeting the substation problem at the mines, with particular reference to the automatic control of such stations. A brief outline of the method of operation and protection provided for both synchronous converter and synchronous motor-generator equipments, is given. Conclusions are drawn as to the advantages of automatic operation.*

* * * * *

THERE is nothing extremely complex or startling in the automatic control of substation machinery; the control of a reversing blooming mill is far more complicated, and any number of inventions and developments of recent years has accomplished more wonderful results. Neither have there been any developments of importance in this control during the past year or more, but, because of the more general application of such control to mining substations, an outline of its principal characteristics and the way it is applied, may be of interest.

Load Characteristics

Before going into the various methods of handling the substation problem, let us consider the character of load to be supplied. A mining load is similar to that encountered in railway service, in that it is a fluctuating load, but the changes in load on the mining substation are much more rapid, often rising in a few seconds from no load to the maximum capacity of the station. While such an overload is usually of short duration, there are times when the machines are worked to the limit of their capacity, for the load factor is usually low and the machines installed are seldom larger than absolutely necessary. Frequent short circuits help to make the problem of providing continuous service an extremely difficult one.

Use of Manually-Operated Substations

There are in use at present three important methods of meeting the substation problem at the mines, by means of manually-operated converting units: (1) Single-unit stations may be placed at important load centers and an attendent provided for each. This is the method from which the best service may be expected. (2) Single-unit stations may be located, not so much with respect to the load as with the idea in mind of placing them near a shop, hoist, pumps, etc., so that they may be given some attention by the men already on duty at such points. (3) When the workings of the mine are so situated that large amounts of power are required in a comparatively small area, so that long feeder runs are unnecessary, there are advantages to be gained by placing two or more machines in the same station and placing a responsible man in charge.

Abridgment of paper presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924. Complete copies to members on request.

Results of Manual Operation

During the last few years, it has become increasingly difficult to obtain capable operators at the mines, except at almost prohibitive rates. The result has been that the service rendered even by attended stations has been far from what might be desired. In many instances, although long feeder runs are required, multi-unit stations have been used in an effort to save in expense for attendence, but the voltage drop in most of such cases has been so excessive that a slowing-up of operations and increased maintenance have resulted. It was because of the many short-comings of manual operation, involving as it does the personal element, consequent expense, and improper locating of substations, that caused the engineers of the larger manufacturers to look into the possibility of applying automatic control to mining substations. Previous experience along similar lines made the development of mining-type automatic substations a comparatively easy task. In addition to many years of control experience in other applications, there were available the actual results of automatic operation of converting units, supplying railway and lighting loads. The first of these was placed in operation in the Union, Illinois substation of the Elgin and Belvidere Electric Railway on Christmas, 1914 and proved so successful that automatic equipment was rapidly installed in all the other substations of the system.

Partially Automatic Stations

While the Union station was the first completely automatic station, there were some partially automatic equipments in operation before that time. These stations were manually started and were provided with a few protective features, so that the attendant might be relieved of some responsibility and yet have the machine and service at least partially protected. Many of the mining substations which are only partially attended are now being protected similarly; bearing temperature relays are mounted on the machines and either a load-limiting resistor or automatic reclosing circuit-breaker used in the d-c. side.

If the station operates in multiple with other stations, the load-limiting resistor permits it to hang on during overloads in excess of its capacity, by shifting only the excess load to the other stations. Contactors open at successively higher current values and insert resistance into the feeder circuit, thereby increasing the voltage drop between the machine and load and thus limiting the fractional part of the load that the machine will assume. The resistance is kept in circuit only so long as the overload continues. If this is long enough to overheat the resistor, a thermal relay opens the d-c. circuit entirely until the resistor has cooled sufficiently to permit resumption of service.

The advantage of this method of overload protection is that only the excess load is shifted, while the opening of any type of circuit breaker throws all of the load on the other stations, and their breakers may also open in succession. The principal disadvantage is its failure to provide proper protection when the other stations are shut down and the station to be protected is operating on stub-end feed. As has already been stated, the current drawn by a series motor on a constant torque load is not decreased when the trolley voltage is lowered. Therefore, cutting resistance into the circuit will not limit the load on stub-end feed, except insofar as the resistor may be designed to limit the current on short circuit to the commutating capacity of the machine. If the haulage load is near the limit of the station capacity and an additional locomotive is started, the resistance will cut in and limit the current during the acceleration of this motor, and in this way be of some use. However, because the rate of acceleration is decreased, the locomotive runner may partly defeat the purpose of this by cutting out more resistance in his controller. Such an equipment is considerably more expensive than an automatic reclosing circuit breaker, and in mining service its use is extremely limited.

It may, therefore, be said that, generally speaking, the automatic reclosing circuit breaker provides the best automatic overload protection for mining substations. Due to the varied conditions under which such an equipment must operate, it should embody the following features:

1. If it is likely to be required to operate on either a stub-end or multiple feeder, it should be capable of proper operation without any adjustment of devices, since the other d-c. source operating in multiple may at any time be connected or disconnected.
2. The tripping, reclosing, and time-delay values should be adjustable independently.
3. The reclosing values for stub-end or multiple feed should be adjustable independently.
4. Construction should be as simple as is consistent with thorough reliability, and all parts should be readily accessible.

An equipment suitable for either stub-end or multiple feed is illustrated in Figs. 1 and 2. Its operation is as follows: When a short circuit or heavy overload occurs on the feeder, the instantaneous overload relay (123) opens, thus de-energizing the coil of the line contactor (118) which opens and disconnects the feeder from the source of power. The (b) interlock on (118) energizes time delay closing relay (102) and, after a predetermined time, it closes its contacts.

Where some other station maintains voltage on the load, (multiple feed), the operation is as follows: After (102) has closed its contacts, contactor (118) will reclose, provided the voltage difference between the load and the source of power has decreased to safe reclosing value, as determined by the voltage-equalizing relay (160).

When the voltage across the load is not maintained by some other station (stub-end feed), the instantaneous

selective control relay (183) immediately closes, because the voltage on its coil is about 250 volts while in multiple feed it is about 25 volts. When both (183) and (102) have closed, the lower coil of the reclosing

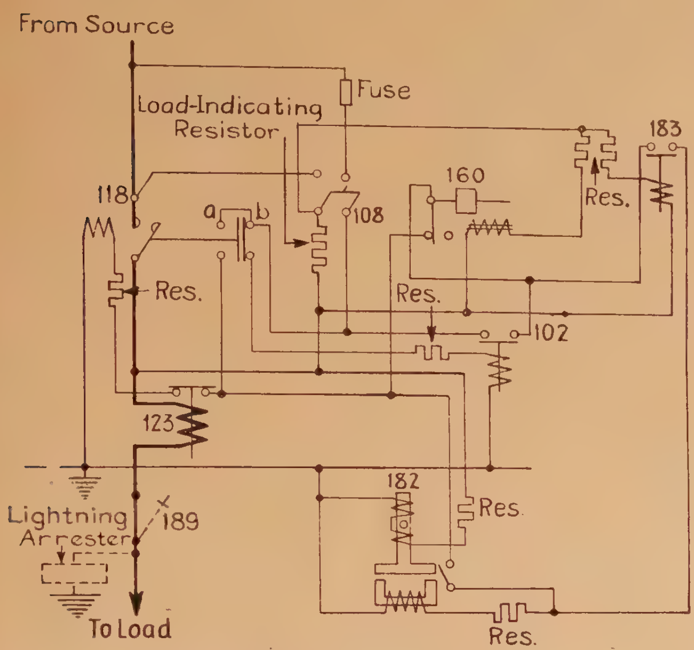


Fig. 1—Wiring for Automatic Reclosing Equipment, Stub or Multiple Feed

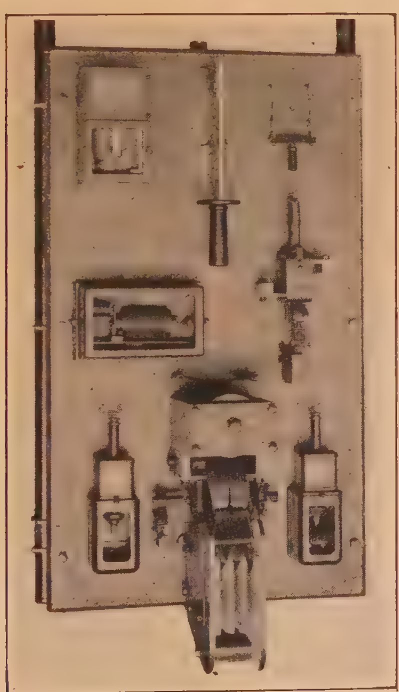


Fig. 2—Automatic Reclosing Equipment Stub or Multiple Feed for 900 Amp. 275-Volt D. C. Feeder

relay (182) is excited from the source of power. When the resistance of the load has increased to a point where the voltage impressed upon the upper coil of (182) reaches the proper value, relay (182) will cause line contactor (118) to reclose as before. On stub-end feed, the voltage across the break of contactor (118) is sufficient to hold relay (160) open.

There are many instances where partially automatic substations are rendering excellent service, and where the additional investment for a completely automatic station would be unjustified. Each has its own field and, if properly applied, they will be equally successful.

Use of Automatic Substations

There are a few differences of opinion as to what constitutes an "automatic substation," but the term is generally understood to mean a station which, upon proper indication by a master element, goes into operation by an automatic sequence, maintains by automatic means the required character of service, shuts down and clears itself upon the opposite indication of the master element, and protects itself while starting, running and shutting down. The master element may be a remote-control switch, time switch, contact-making voltmeter, etc., or the station may be started and stopped by switching the a-c. supply. Because of the fact that the cost of electrical energy is usually only a few per cent of the cost per ton of coal or ore loaded for shipment, it is usually best to start the equipment in the morning by some device, such as a remote-control switch, and permit it to run continuously during the hours when it may be needed suddenly.

Because of the numerous ways in which the automatic station may be started, it may be located in the most advantageous position with respect to the load. The units may also be properly distributed so as to maintain good trolley voltage without having to consider the expense of additional operators, for one man can give a large number of automatic stations the necessary inspections.

Operation and Protection of Automatic Substations

As the manufacturers of automatic control equipments are always ready to furnish complete and detailed information as to the operation of their apparatus, only a general description will be given in this paper.

I. *Synchronous Converter Equipments.* Figs. 3 and 4 illustrate the elementary wiring and control panels respectively of a 150-kw. 275-volt synchronous converter equipment with a combined stub-end or multiple-feed automatic reclosing equipment for the d-c. side. In Fig. 3 the contacts and coils of the devices are not shown together, but are placed in their respective circuits. They are also arranged from left to right, as far as possible, in the order in which they operate in the starting sequence.

The station may be started and stopped either by remote control switch (1-A) or by throwing switch (1) to the right. The resistance (1-B) is approximately equal to the resistance of the pilot circuit in order to

keep the total resistance in the coil circuit of a-c. undervoltage relay (27) approximately the same with either method of starting, thus avoiding a change in the calibration of the relay. In order that the station may be placed in operation from the remote point, manually-operated oil circuit breaker (7), control power switch (8), d-c. control switch (108) and d-c. line switch (189) must be closed. With switch (8) closed, the 220-volt control bus is energized from control transformer (11).

Since the principal steps in the sequence are indicated in Fig. 3 and a rather complete description of the operation is given in the paper as presented, none of the details will be dwelt upon in this abridgment.

II. Synchronous Motor-Generator Equipments. The general scheme of operation of motor-generator equipments is very much the same as that for converters, as will be readily apparent from reference to Figs. 5 and 6 which illustrate a typical mining-type synchronous motor-generator equipment.

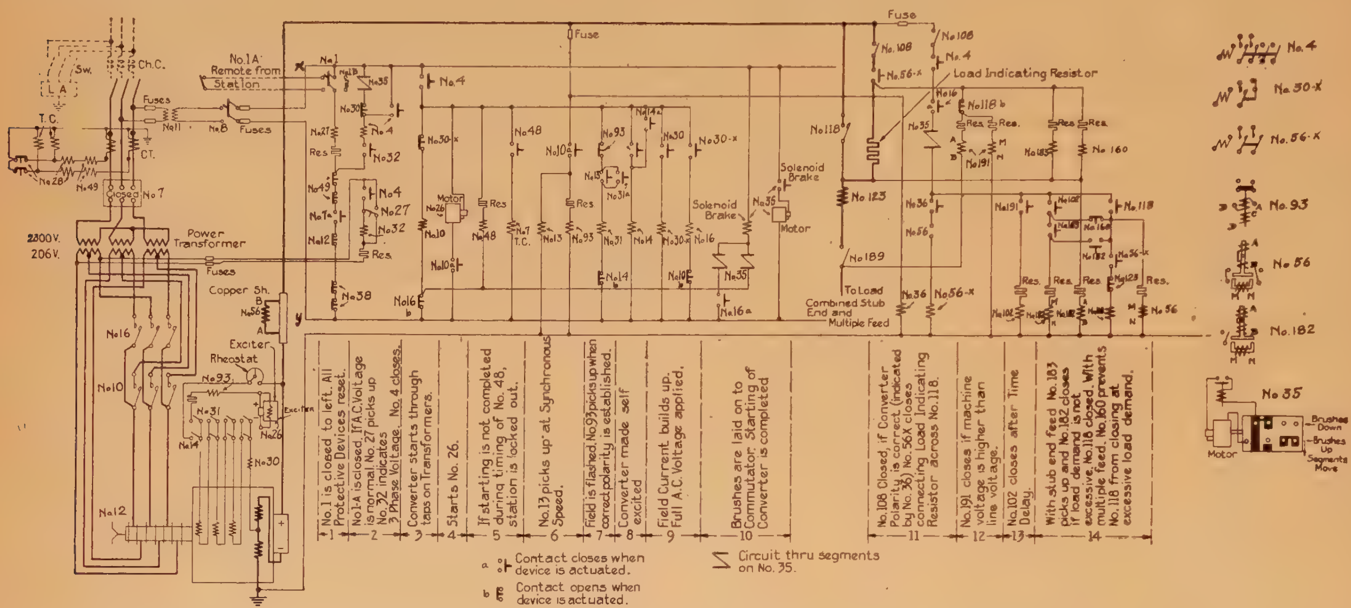


FIG. 3—ELEMENTARY WIRING, SYNCHRONOUS CONVERTER EQUIPMENTS WITH AUTOMATIC RECLOSING FEEDER EQUIPMENT FOR STUB OR MULTIPLE FEED

1—Master Starting Element (Station); 1A—Master Starting Element (Remote); 1B—Pilot Wire Balance Resistance; 4—Master Control Contactor; 7—Oil Circuit Breaker; 8—A-C. Control Power Switch; 10—Starting Contactor; 11—Control Power Transformer; 12—Speed-Limit Switch; 13—Synchronous Speed-Control Relay; 14—Full-Field Contactor; 16—Running Contactor; 26—Motor-Driven Exciter; 27—A-C. Undervoltage Relay; 28—A-C. Overload Time-Delay Relay; 30—Machine Field Relay; 30X—Auxiliary Contactor for No. 30; 31—Field-Flashing Contactor; 32—Single-phase Starting Protective Relay; 35—Brush-Operating Mechanism; 36—Polarized Relay; 38—Bearing Temperature Relay; 48—Starting Protective Relay; 49—A-C. Machine Temperature Relay; 56—D-C. Reverse-Power Relay; 56X—Auxiliary Contactor for No. 56; 93—Field-Changing Relay; 102—Time-Delay Closing Relay; 108—D-C. Control Power Switch; 118—D-C. Line Contactor; 123—D-C. Overload Relay; 160—D-C. Voltage-Balance Relay; 182—D-C. Reclosing Relay; 183—D-C. Selective-Control Relay; 189—D-C. Line Switch; 191—D-C. Voltage Directional Relay.

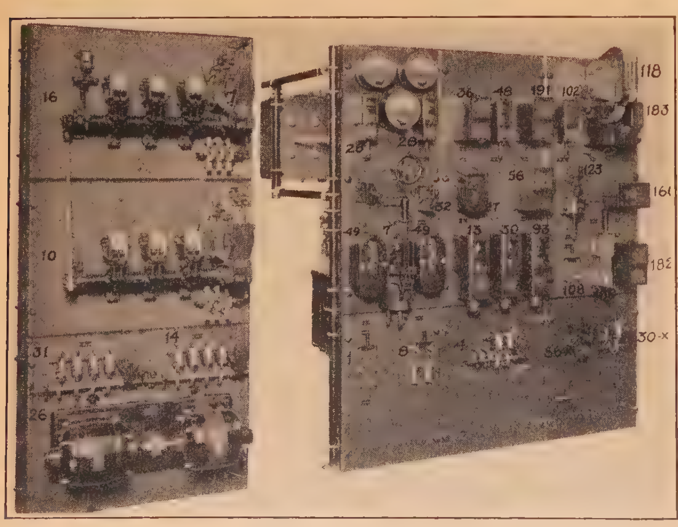


FIG. 4—AUTOMATIC SWITCHING EQUIPMENT FOR SYNCHRONOUS CONVERTER, 275 VOLTS, 150 KW. 6 PHASE, 60 CYCLES

Any one of several methods may be used to place this station in operation; with all switches closed, the a-c. line may be energized by closing an oil circuit breaker in another station, or an authorized person may enter the station and start by closing switch (1) to the right, or remote-control switch (1-A) may be used in the same manner as for converter equipments.

When switch (1-A) is closed, the coil of a-c. undervoltage relay (27) is energized, if the protective devices are in positions indicating normal conditions. Relay (27) then closes its upper contacts whenever the incoming voltage is sufficiently high for proper operation. Single-phase starting protective relay (32) can then pick up, if all three phases are energized, for it will be seen that relays (32) and (27) are connected to different phases. Relay (32) in closing, completes the circuit to the coil of master-control contactor (4) which closes. This contactor controls the remaining a-c.

contactors and relays and also the d-c. automatic reclosing equipment. The remaining steps in the sequence, together with the nomenclature of devices is given in Fig. 5, and no further explanation will be given here.

III. General. From the foregoing discussion, it may be seen that the sequence of operation follows approved practise for manual operation, with the advantage that each step is performed at the proper time without the possibility of error. While only

2. Severe overload on the d-c. side of the machine. Relay (123) trips out contactor (118). The reclosing of the contactor takes place after (102) has completed its timing and either (182) or (160) has closed its contacts, depending upon whether the operation is stub-end or multiple feed.

3. Incomplete start. A long-time delay relay (48) is deenergized by the closing of contactor (4) and is reenergized by the closing of running contactor (16). This relay will trip out oil circuit breaker (7) and shut

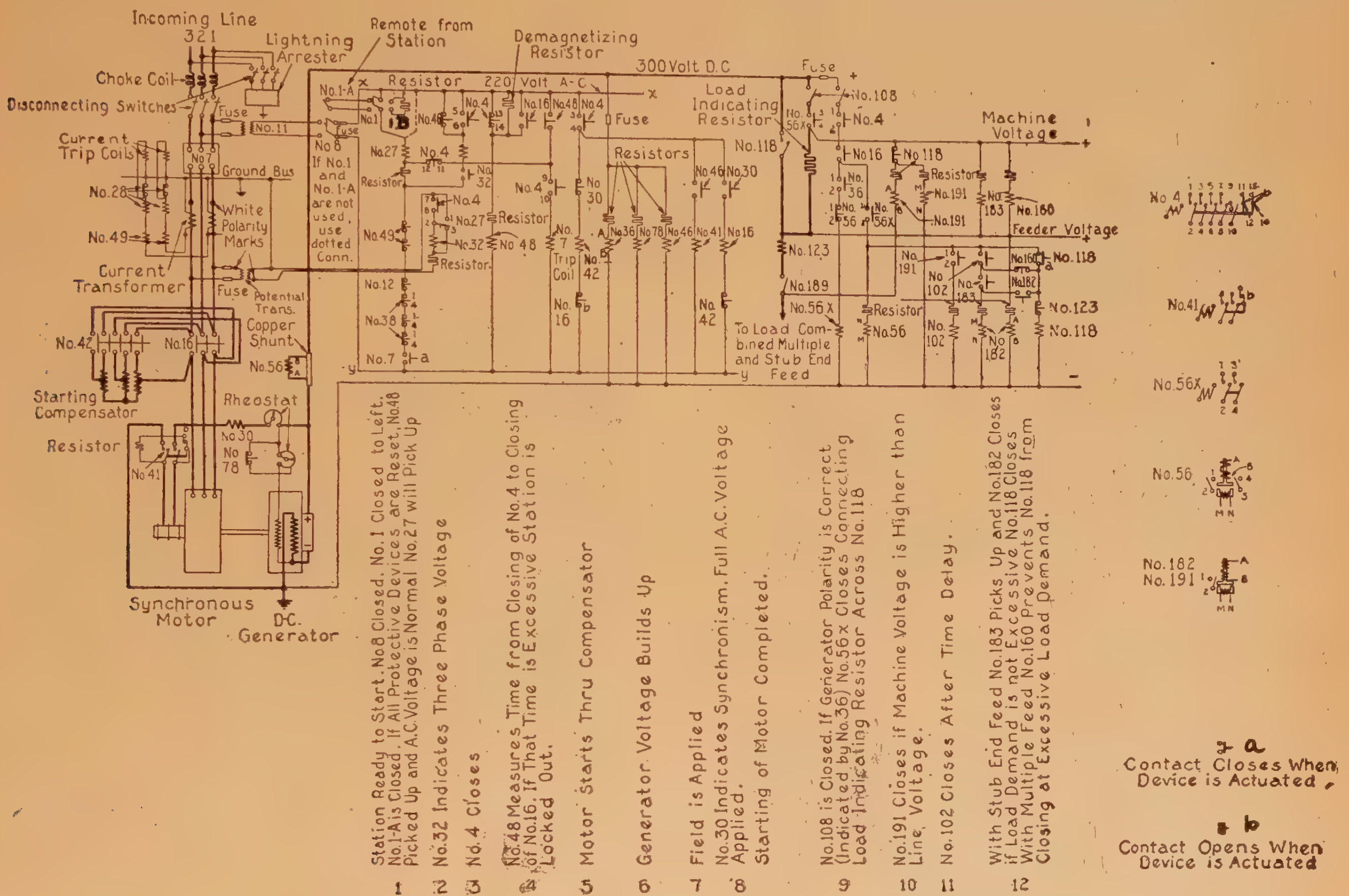


FIG. 5—ELEMENTARY WIRING FOR SYNCHRONOUS MOTOR-GENERATOR EQUIPMENTS WITH AUTOMATIC RECLOSING FEEDER EQUIPMENT FOR STUT OR MULTIPLE FEED

1—Master Starting Element (Station); 1A—Master Starting Element (Remote); 1B—Pilot-Wire Balance Resistance; 4—Master Control Contactor; 7—Oil Circuit Breaker; 8—A-C. Control Power Switch; 11—Control Power Transformer; 12—Overspeed Limit Switch; 16—Running Contactor; 27—A-C. Undervoltage Relay; 28—A-C. Overload Time-Delay Relay; 30—A-C. Machine Field Relay; 32—Single-Phase Starting Protective Relay; 36—Polarized Relay; 38—Bearing-Temperature Relay; 41—Motor-Field Contactor; 42—Compensator Magnetizing Contactor; 46—Generator Relay; 48—Starting Protective Relay; 49—A-C. Machine-Temperature Relay; 56—D-C. Reverse-Power Relay; 78—Field-Building Relay; 102—Time-Delay Closing Relay; 108—D-C. Control Power Switch; 118—D-C. Line Contactor; 123—D-C. Overload Relay; 160—D-C. Voltage-Balance Relay; 182—D-C. Reclosing Relay; 183—D-C. Selective-Control Relay; 189—D-C. Line Switch, 191—D-C. Voltage Directional Relay.

single-unit equipments have been discussed, only minor changes are necessary, if two or more units are installed in the same station.

The protection provided for either synchronous converters or synchronous motor-generators may be summarized as follows:

1. Severe overload on the a-c. side of the machine. Relays (28) trip out oil circuit breaker (7) and the auxiliary switch causes all control devices to drop out. This will happen only under abnormal conditions, and the station must be visited and inspected before it can restart.

the set down until inspected, if the time of starting is delayed beyond the time interval for which it is set.

4. Loss of field excitation. Relay (30) will drop out, opening running contactor (16) and closing the starting contactor. Line contactor (118) is opened, and if the field is permanently lost, relay (48) will shut the machine down.

5. Connecting the machine to the line with wrong polarity. Relay (36) holds its contacts open, thus preventing line contactor (118) from closing.

6. Single-phase starting and undervoltage on incoming line. A sensitive relay (27), working through

single-phase starting protective relay (32), provides the low-voltage protection. When low voltage occurs, the lower contacts of (27) are closed and short-circuit the coil of relay (32). Relay (32) opens and interrupts the supply to the coil of contactor (4), thus shutting the station down. Should single-phase current exist

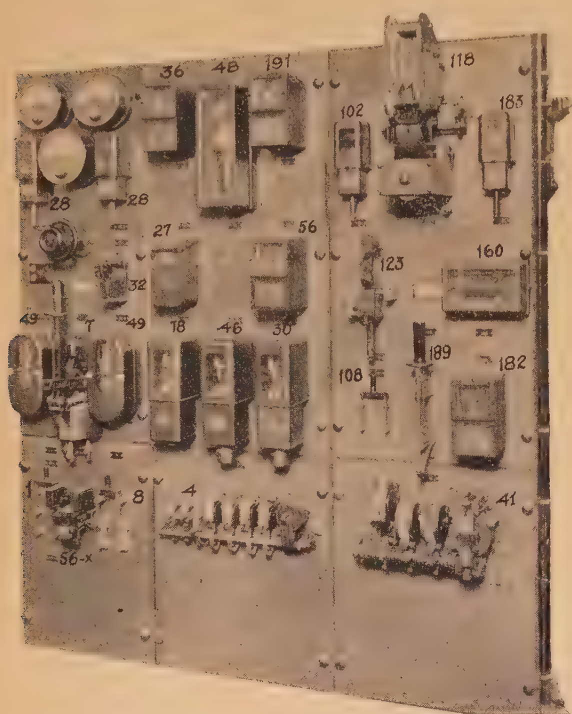


Fig. 6—Automatic Switching Equipment for Motor Generator Set 250/275-Volts, 150 Kw. and Combined Stub End and Multiple D. C. Reclosing Feeder

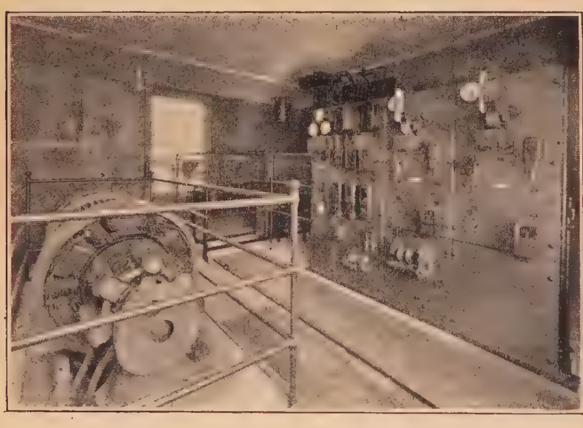


Fig. 7—150 Kw. 250/275-Volt D. C. 2300-Volt 3-Phase 60-Cycle Synchronous Motor-Generator with Automatic Control Equipment, Rimerton Coal Company, Rimerton, Pa.

on the incoming lines, either relay (27) or (32) is de-energized and the motor cannot be connected to the a-c. line.

7. Overheated bearings. The bearing thermal relays (38) are provided to protect the unit by opening the coil circuit of contactor (4), should a bearing become overheated. These are hand reset and require the presence of an inspector to put the machine into service again. Usually a little scraping is all that the bearing requires.

8. Overheated machine windings. Machine thermal relays (49) connected to the current transformers, prevent the overheating of the machine windings. They have a thermal characteristic similar to that of the machine, except that they are calibrated to operate slightly ahead of the danger point. On cooling, service is restored. These relays provide indirect protection against single-phase operation, since if one phase fails, the remaining phases carry excessive current and when this tends to overheat the machine, the relays trip.

9. Overspeed. A speed limit switch (12) is provided, which, in case of overspeed, opens contactor (4) and cuts the machine off on both the a-c. and d-c. sides. As this switch is hand reset, the station must be inspected before it can restart.

10. Reverse power protection is provided by relay

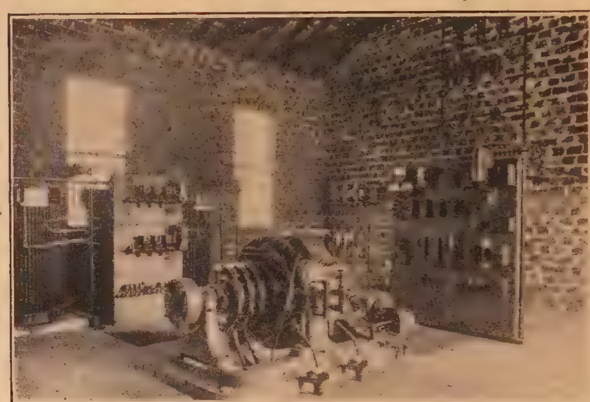


Fig. 8—Automatic Switching Equipment and Synchronous Converter 275 Volts, 200 Kw. 6 Phase, 60 Cycles—Clearfield Bituminous Coal Corp., Grass Flat, Pa., Pleasant Hill Mine

(56). Any reversal of current will cause relay (56) to open contactor (118). Voltage directional relay (191) is then in control of the contactor. After enough load has again come on the feeder to pull its voltage below that of the generator, relay (191) permits the contactor to reclose. The reverse-power relay opens the machine circuit before the set can be overspeeded from the d-c. side. As an extra precaution, however, the speed limit switch (12) is provided.

11. Temporary drop in a-c. voltage sufficient to drop out running contactor (16) and control contactor (4). Contactor (4) cannot reclose until relay (30) of the converter equipment or relay (46) of the motor-generator equipment has dropped out. This necessitates the machine going through the usual starting sequence in resuming operation.

12. Converter equipments are further protected against starting with the brushes down or going on the d-c. line with brushes raised. This is accomplished by

the drum switch attached to the motor-operated brush mechanism (35).

The protective features may be divided into two classes: automatic reset and hand reset. If the trouble is apt to be of a temporary nature such as overheated machine windings, low a-c. voltage, or overload on the d-c. side, a device is used which will automatically reset when conditions return to normal. If the trouble is likely to be of a permanent nature or such that the station should be inspected or repairs made before service is restored, a hand reset device is used. The protection provided against overheated bearings, overspeed or failure to complete the starting sequence, is of this type.

Results of Automatic Operation

As has been stated elsewhere in this paper, each type of substation, manual, partially automatic, and completely automatic, has its own field of application, and each may be misapplied. From an engineering viewpoint, there are no reasons why an automatic substation cannot be used wherever a manual substation will operate without undue attention from the operator, but there are many places where the extra investment would be entirely unwarranted. However, when properly applied, the single-unit automatic substation should pay for the extra investment in from one to three years, depending upon the number of shifts, merely from reduction in operating expenses and neglecting other less tangible savings.

The speeding-up of all the operations in the mine by improved voltage regulation and the reduction in time lost because of interruptions in service, make possible an increase in output of the mine without the addition of any mining equipment or increase in substation capacity. When a manually-operated breaker trips on overload or short circuit, the operator waits a short time and then attempts to reclose it. If it comes out again, he waits and then tries again. Should it still refuse to stay in, he will probably sit down for awhile before trying a third time. In the meantime, the trouble may have been cleared, and an automatic reclosing circuit breaker would have lost no time in restoring service.

Decreased maintenance on motors, because of better trolley voltage, and on converting equipment, by elimination of unskillful handling, and reduced copper losses, are also economic advantages which cannot be disregarded. Let us assume that a 300-kw. 275-volt machine is supplying a mine through a 1,250,000-cir. mil feeder and a 4/0 trolley, tied together at intervals; also that the negative return consists of two 45-lb. rails well bonded. The voltage drop to a point one mile away from the substation, with 1090 amperes or full-load current flowing, is 109 volts, so that a motor at that point will have only 166 volts impressed upon it. It is seldom realized that in this same system, the loss at full load will be 119 kw. or almost 40 per cent of the rating. The conditions, as stated in the foregoing, are even better than those found in most mines, for it is an exceptional mine that has the proper amount of copper installed, and the rail bonds are generally in poor condition.

The conclusion may therefore be drawn that, while there are many cases in which an automatic station is not justified, there is no question about its economy when properly applied. Whenever conditions are such that additional substation capacity appears necessary, the whole situation should be given careful consideration, for a redistribution of converting units may be all that is required.

OLDEST LIGHTHOUSE IS ELECTRIFIED

Cape Henry Light Station, the oldest beacon in the United States, and the first public work to be undertaken by the American government in 1790, has lately completed a cycle in lighting that began with crude lamps burning fishoil and wound up with electric light. For nearly a century the sandstone tower withstood the gales that roared across the mouth of the Chesapeake, and during that time the fuel that fed its battery of lamps was changed five times. First fish-oil, then sperm-whale oil, then colza oil, then lard oil, and finally kerosene burned in front of the silvered reflectors.

In 1881 the ancient tower began to crack, and for that reason beside it was built another tower, of masonry and iron. The lamps and reflectors were transferred to the new beacon, 165 feet high, from whose top the 6000 candle power light could be seen nearly 20 miles.

In 1910 the kerosene lamps were discarded, and oil-vapor lamps of 22,000 candlepower were substituted, again increasing the range of visibility. About a year and half ago an experimental installation of electric light was made, using a 1000-watt tungsten filament lamp with a clear white beam of 80,000 candlepower.

A recent report upon the new light declares it a complete success and more dependable than any of the lights that preceded it. At the side of the electric lamp is an automatic device holding a second lamp, ready to swing it into focus in front of the great lenses if the first should fail. The equipment, electrically operated, will bring the new lamp into position and light it in less than one second without interruption of the flashing signals.

QUALIFICATION TESTS FOR DRY CELLS

A series of tests on dry cells, undertaken with the purpose of obtaining a list of acceptable dry cells for use of Government purchasing officers, is under way. Arrangements have been made whereby sample cells will be selected at the plants of the cooperating manufacturers by a Bureau inspector.

Short Circuits of Alternating-Current Generators

BY C. M. LAFFOON

Power Engineering Dept., Washington Electric and Mfg. Co.

Review of the Subject.—*In this paper, the author presents a physical conception and simple non-mathematical analysis of the short-circuit phenomena of alternating-current generators. Formulas are developed for the maximum instantaneous values of the armature and field short-circuit currents delivered by both single and polyphase generators, which are equipped with and without damper windings.*

* * * * *

THE physical phenomena resulting from the short circuit of alternating-current generators are becoming more or less familiar to the interested electrical designing, and operating engineers.

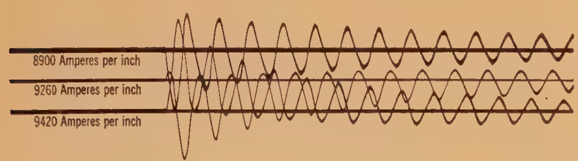


FIG. 1—SHORT-CIRCUIT TEST ON 6250-KV-A. TURBO-ALTERNATOR

60 cycles, 3600 rev. per min., 6600 volts per phase. Star-connected Oscillogram shows current in three phases, 100 per cent voltages.

From the practical standpoint, the most important phases of the short-circuit phenomena of a-c. generators are:

(a) the maximum peak values of the armature and field currents that are reached during the first half-cycle after the short circuit occurs:

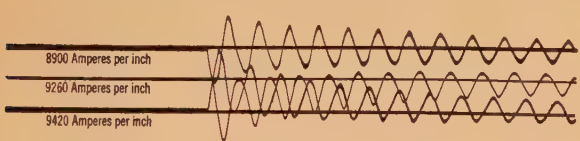


FIG. 1A—SHORT-CIRCUIT TEST ON 6250-KV-A. TURBO-ALTERNATOR

60 cycles, 3600 rev. per min., 6600 volts per phase. Star-connected Oscillogram shows current in three phases, 75 per cent voltage.

(b) the rate of decrease of the peak and r. m. s. values of the current waves for the armature and field circuits; and

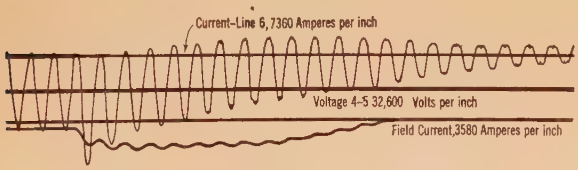


FIG. 2—SHORT-CIRCUIT TEST TURBO-GENERATOR

12,500 kv-a., 13,200 volts, 60 cycles, 3-phase, 1800 rev. per min.

(c) the final or sustained values of the armature current.

Abridgment of paper presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924. Complete copies to members on request.

FUNDAMENTAL FLUX RELATIONS FOR A SINGLE-PHASE GENERATOR

In the simple type of single-phase generator shown in Fig. 5, the stationary and rotating elements are both considered to be perfectly laminated and to have infinite permeability. The stationary element is provided with an armature winding, $A\,A_1$, which is uniformly distributed over a portion of the armature periphery and has N_a turns, all of which are connected in series. The salient pole rotor has a field winding, $P\,P_1$, of N_1 turns connected in series. When a direct current, I_1,

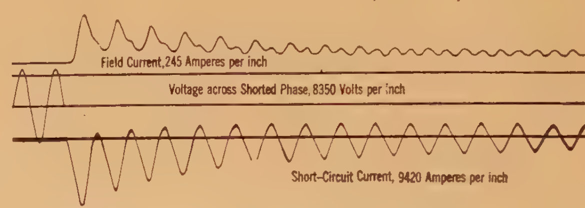


FIG. 3—SHORT-CIRCUIT TEST ON 6250-KV-A. TURBO-GENERATOR

60 cycles, 3600 rev. per min., 6600 volts per phase, single-phase test, voltage across short-circuited phase, current in single-phase test, voltage across short-circuited phase, current in short-circuited phase, and field current. 50 per cent voltage.

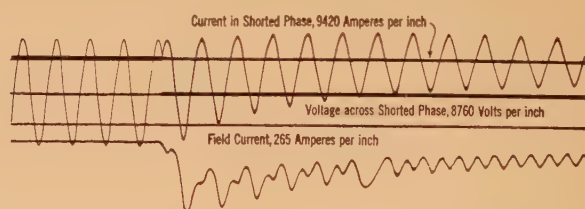


FIG. 4—SHORT-CIRCUIT TEST ON TURBO-ALTERNATOR, 6250 KV-A.

60 cycles, 3600 rev. per min., 6600 volts per phase. Single-phase test. Current and voltage in short-circuited phase and field current. 75 per cent voltage.

flows in the field circuit a total magnetic flux, I_1, ϕ_1, is produced which interlinks these windings as shown by the dotted lines in Fig. 5. In the above expression, the symbol, ϕ_1, is defined as the total flux produced by the field circuit when one ampere flows in it. This total field flux, ϕ_1, per ampere, consists of two parts; ϕ_{m1a}, which interlinks the armature circuit as well as the field circuit and ϕ_{1L} which interlinks only the field circuit. When one ampere flows in the field circuit, its total flux interlinkages are $K_1\,N_1\,\phi_1$, where N_1 is the number of turns and the factor K_1 is introduced on account of the

fact that the total flux does not interlink all of the field turns. This product is usually designated by the symbol, L_1 and is defined as the total self-inductance or coefficient of self-induction of the field winding. In a similar manner the quantity, $\mathfrak{L}_1 = k_{1L} N_1 \phi_{1L}$, is defined as the coefficient of leakage self-induction of the field circuit. Similarly, the flux interlinkages of the armature circuit due to one ampere flowing in the field circuit are equal to, $K_{m1a} N_a \phi_{m1a}$, which is defined as the coefficient of mutual induction between the armature and field circuits and is represented by the symbol, m_{1a}.

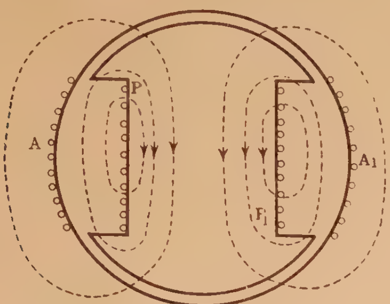


FIG. 5

Using a similar system of notation, the corresponding induction coefficients of the armature circuit can be written and defined as follows:

$L_a = K_a N_a \phi_a$, coefficient of total self-induction of the armature circuit.

$\mathfrak{L}_a = K_{la} N_a \phi_{la}$, coefficient of leakage self-induction of the armature circuit.

$M_{a1} = K_{ma1} N_1 \phi_{ma1}$, coefficient of mutual induction of the armature and field circuits.

The coefficient of total self-induction of the armature circuit is not constant for all rotor positions on account

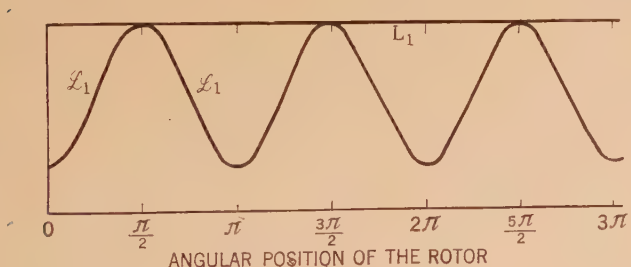


FIG. 6

of the salient pole construction of the rotor. The leakage induction coefficient of the armature circuit varies between maximum and minimum values according to the same general law as for the similar coefficient of the field circuit. The relation between the total and leakage induction coefficients of the armature circuit is shown by the curves in Fig. 8.

It is well known from the laws of physics that the mutual induction coefficient of two inductively coupled circuits is the same for either circuit with respect to the other; that is, in the case under consideration, $M_{a1} = M_{1a}$, and $K_{m1a} N_a \phi_{m1a} = K_{ma1} N_1 \phi_{ma1}$. Under this condition the curve in Fig. 7 shows the variation of the mutual induction coefficient of either the field circuit with respect to the armature circuit or the armature circuit with respect to the field circuit for any angular position of the rotor.

If the induction and resistance coefficients of the circuits are known, the magnitude of the currents can be readily determined for both stable and transient conditions when the voltage or flux relations are known. However, under transient short-circuit conditions a better physical conception and simpler analysis of the flux and currents during the first half cycle after the short circuit occurs can be had by assuming the armature and field circuits, both, to have zero resistance. Under this assumption, the instantaneous values of the short-circuit currents for the different circuits can be easily obtained by applying Lenz's and Kirchhoff's Fundamental Laws which can be stated as follows:

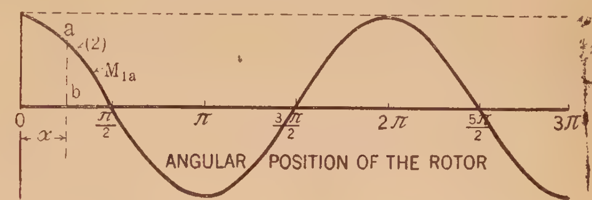


FIG. 7

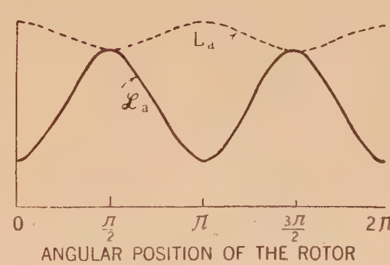


FIG. 8

"If a closed electric circuit has a given number of flux lines interlinking it, any *change* or *variation* in the number of flux interlinkages will cause a current of sufficient magnitude to flow in the circuit in such direction that the initial flux interlinkages of the circuit are maintained constant."

Maximum Instantaneous Value of Short-Circuit Current

Single-Phase Generator Without Damper Winding. If the armature circuit of the single-phase generator is suddenly short-circuited at the instant the axis of the field winding coincides with the axis of the armature winding, as shown in Fig. 5, the initial flux interlinkages which must be maintained constant, are $I_1 L_1$, and $I_1 M_{1a}$, respectively for the two circuits. At an instant later, when the rotor has turned through a small angle α the initial flux interlinkages of the armature circuit are decreased. Consequently, a current will flow in

this winding tending to supply the decreased amount of flux interlinkages. However, when a current flows in the armature circuit it not only produces a flux interlinkage with itself, but also adds additional flux interlinkages to the field circuit. These additional flux interlinkages of the field circuit will in turn tend to be neutralized by an opposing flux set up by a secondary current in the field circuit. At any instant the currents in the two circuits must be of such magnitude that the resultant flux interlinkages of each circuit due to the combined action of all currents are the same as at the instant that the short circuit occurred.

When the rotor is in the angular position shown in Fig. 9, none of the field flux interlinks the armature circuit and the total change of its flux interlinkages are I_1, M_{1a}. At this instant the leakage and total self-induction coefficients of the armature circuit are one and the same as shown by Fig. 8. Consequently, the current, i_a, that flows in the armature circuit must be such that its total flux interlinkages are equal to the change in its initial flux interlinkages.

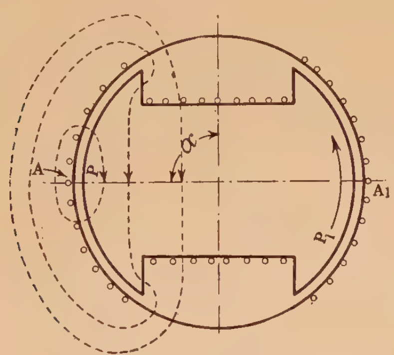


FIG. 9

That is,

$$i_a L_a = i_a \mathcal{L}_a = I_1 M_{1a}, \text{ or}$$

$$I_a = \frac{I_1 M_{1a}}{L_a} = \frac{I_1 M_{1a}}{\mathcal{L}_a} \qquad (1)$$

At this instant, there is no current flowing in the field circuit except the normal exciting current, I_1.

When the rotor has turned through 180 degrees as shown in Fig. 10A, the interlinkages of the armature circuit due to the exciting current, I_1, in the field circuit are the same as at the instant of short circuit but interlink it in the reverse direction. Hence, the total change in the normal field flux interlinking the armature circuit is from $I_1 M_{1a}$ to $-I_1 M_{1a}$ or $2 I_1 M_{1a}$. The current, i_a, that flows in the armature circuit produces a total flux interlinkage, $i_a L_a$, with itself. This total flux interlinkage consists of the leakage flux interlinkages, $i_a \mathcal{L}_a$, and the flux interlinkages $i_a M_a$ due to the mutual flux as shown in Fig. 10B. The corresponding flux interlinkages of the field circuit, due to the normal flux are, $i_a M_{a1}$. Since the interlinkages of the field circuit must be maintained at a constant value $I_1 L_1$, the flux interlinkages of the field circuit due to its secondary current, i_1, must be equal to the mutual flux interlinkages from the armature circuit.

That is,

$$i_1 L_1 = - i_a M_{1a}, \text{ or}$$

$$i_1 = - i_a M_{1a}/L_1 \qquad (2)$$

For the purpose of analysis, the flux interlinkages $i_a M_{a1}$, of the field circuit due to the armature current

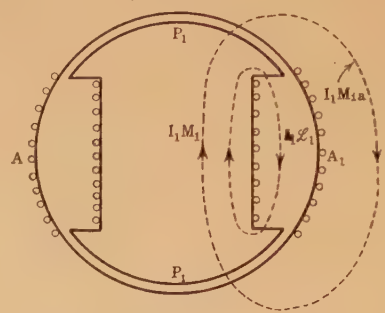


FIG. 10A

α = 180 deg. $I_1 L_1 = I_1 L_1 + I_1 M_1$

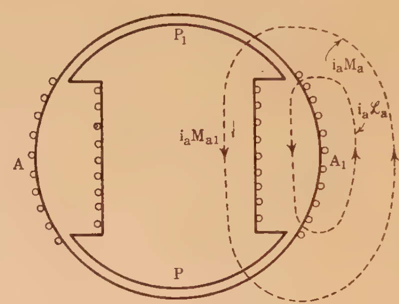


FIG. 10B

α = 180 deg. $i_a L_a = i_a L_a + i_a M_a$

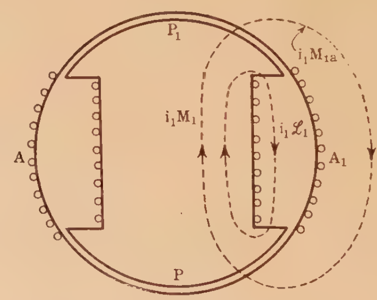


FIG. 10C

α = 180 deg. $i_1 L_1 = i_1 L_1 = i_1 M_1$

can be separated into the two components, $K' i_a M_{a1}$, and $(1 - K') i_a M_{a1}$, where K' is a constant for this particular rotor position. In a like manner, the flux interlinkages of the armature circuit due to its own mutual flux can be divided into two components, $K'' i_a M_a$, and $(1 - K'') i_a M_a$. Fig. 11 shows the components of the flux interlinkages of both circuits due to the currents, i_a and i_1, on the basis that the resultant flux interlinkage of each circuit is the same

as at the instant of short circuit. (The flux interlinkages due to the normal field current are not shown for the sake of clearness.)

From Fig. 11 the following flux interlinkage relations for the field circuit are evident.

$$i_1 M_{1a} = - i_a M_{a1} (1 - K') \quad (3)$$

$$i_1 \mathcal{L}_1 = - i_a M_{a1} K' \quad (4)$$

Therefore,

$$i_1 M_{1a} + i_1 \mathcal{L}_a = - i_a M_{a1} (1 - K') - i_a M_{a1} K', \text{ or}$$

$$i_1 L_1 = - i_a M_{a1} \quad (5)$$

That is, the total flux interlinkages of the field circuit due to the current, i_1, are equal to and neutralized by the total mutual component of the armature flux interlinkages, consequently the only flux interlinkages of the field circuit are $I_1 L_1$ which are the same as the initial value.

From Fig. 11 the following flux interlinkage relations must be satisfied for the armature circuit at this angular position,

$$i_a M_a (1 - K'') = i_1 M_{1a} \quad (6)$$

$$i_a M_a K'' + i_a L_a = \text{resultant flux interlinkages for the armature circuit} \quad (7)$$

Since the resultant flux interlinkages of the armature circuit must be equal in magnitude to the total change in its initial flux interlinkages.

$$i_a M_a K'' + i_a \mathcal{L}_a = 2 I_1 M_{1a} \quad (8)$$

In other words, the magnitude of the armature current must be such that its leakage flux interlinkages plus the

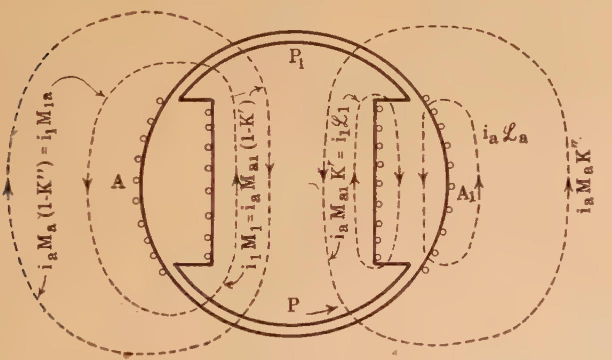


FIG. 11

$\alpha = 180$

leakage flux interlinkages of the field circuit (expressed in terms of the armature circuit constants) due to the proportional secondary current, i_1, equals the total change in the initial flux interlinkages of the armature circuit. It is usually more convenient to express the sum of the leakage flux interlinkages of the two circuits in terms of an equivalent leakage flux interlinkage of the armature circuit alone. Substituting the value of i_1 from equation (2) in equation (6) gives

$$K'' = 1 - \frac{M_{a1}^2}{L_1 \ M_a} \quad (9)$$

But

$$\mathcal{L}_a = L_a - M_a \quad (10)$$

Substituting the values of K'' and $\mathcal{L}_a$ in equation (8) gives

$$i_a (L_a - M_{a1}^2/L_1) = 2 I_1 M_{1a}, \text{ or}$$

$$i_a = \frac{2 I_1 M_{1a}}{L_a - M_{1a}^2/L_1} \quad (11)$$

And from equation (2)

$$i_1 = - i_a M_{1a}/L_1, \text{ or},$$

$$i_1 = - \frac{2 I_1 M_{1a}}{L_a - M_{1a}^2/L_1} \times M_{1a}/L_1 \quad (12)$$

The quantity, $L_a - M_{1a}^2/L_1$, is defined as the coefficient of the equivalent leakage induction of the armature circuit when the angular position of the rotor is such that the axes of the two windings coincide.

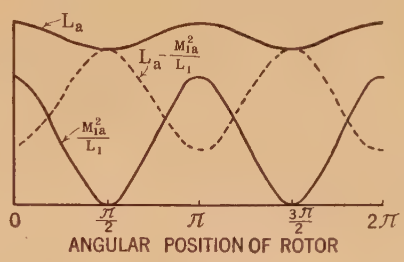


FIG. 12

The general equations for the values of the armature and field currents under any short circuit can now be stated as follows:

$$i_a = \frac{\text{Change (due to rotation) in normal field flux interlinkages of the armature circuit}}{\text{Coefficient of equivalent leakage self-induction of the armature circuit}} \quad (13)$$

$$i_1 = - i_a \times \frac{\text{Mutual induction coefficient of the armature circuit with respect to field circuit}}{\text{Total self-induction coefficient of the field circuit}} \quad (14)$$

In the preceding discussion the circumferential width of the armature phase band has not been limited to any specific value. It is well known that the flux interlinkages of a single-phase armature winding vary approximately as the sine of one-half the width of the phase belt, even though the field form does not have a sinusoidal distribution around the armature periphery. The relation between the total equivalent leakage self-induction coefficient, $L_a - M_{1a}^2/L_1$, and the width of the armature belt can be obtained either by calculation or test. The total induction coefficient increases faster than the first power of the phase belt width as shown by curve 1 in Fig. 13. Since the mutual induc-

tion coefficient varies sinusoidally with respect to the width of the phase belt and the magnitude of the field self-induction coefficient is independent of the width of the armature phase belt, the quantity, M_{1a}^2/L_1 will vary approximately as the sine square law as shown by curve 2 in Fig. 13. Curve 3 of this figure shows that the equivalent leakage self-induction coefficient increases faster than the first power of the width of the winding belt. Then by knowing the total change in flux interlinkages, $K\, I_1\, M_{1a}$, and using the total equivalent leakage induction coefficient of the armature circuit from curve 3 of Fig. 13, the maximum possible instantaneous value of the armature current under particular short-circuit conditions can be determined from Equation 11 and plotted as shown by curve 3 of Fig. 14. This curve indicates that the maximum value of the armature current increases as the width of the phase belt decreases. This relation is based on the fact that the

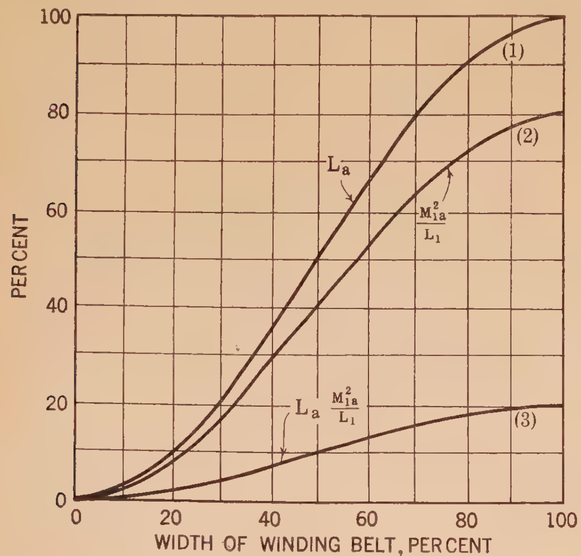


FIG. 13

field flux is constant and the number of conductors in the armature circuit increases directly with the width of the phase belt. Hence, the ordinate $\overline{a_1\, b_1}$ gives the maximum value of armature current when one leg of a delta-connected winding or one leg,—terminal to neutral, of a star-connected winding is short-circuited. Ordinate $\overline{a_2\, b_2}$ shows the maximum value of the armature current when one leg of a two-phase winding is short-circuited. Similarly, $\overline{a_3\, b_3}$ is the maximum armature current delivered when a star-connected winding is short-circuited between two terminals. And $\overline{a_4\, b_4}$ shows the current delivered by a single-phase generator with all of the periphery wound.

Single-Phase Generator with Damper Winding

If the rotor of the single-phase generator is equipped with a damper winding, $D\, D_1$, located at right angles to the field winding, $P\, P_1$, the resultant flux interlinkages of it due to the field current are zero. Under no-load conditions, the flux interlinkages of the armature circuit, due to the normal field flux are the same as for the single-phase generator without a damper winding as was shown in Fig. 7. Hence, in this case, if the armature is suddenly short-circuited at any angular position, of the rotor the initial flux interlinkages, $I_1\, L_1$, for the field current $I_1\, M\alpha_{1a}$, for the

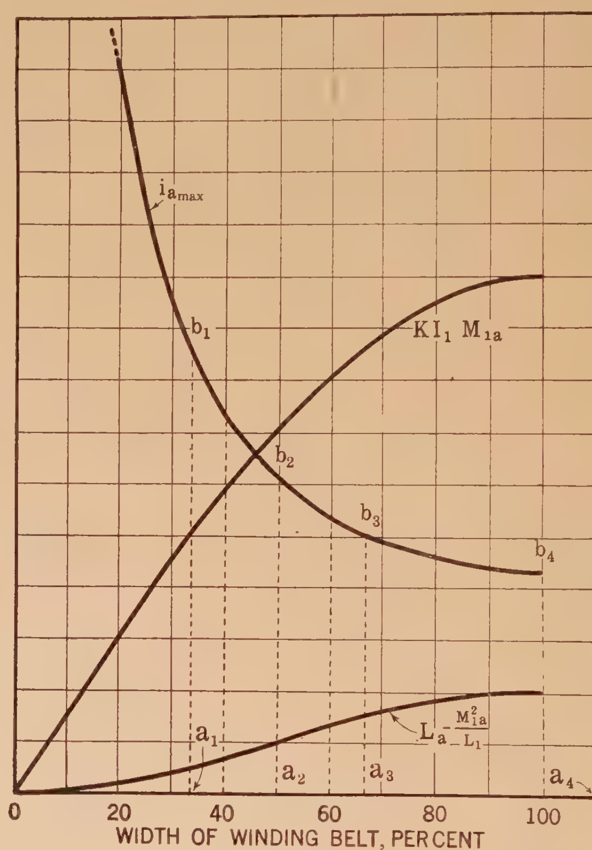


FIG. 14

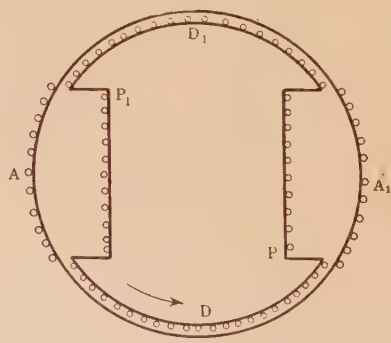


FIG. 15

$\alpha = \pi$

armature circuit, and zero for the damper circuit must be maintained constant for all other angular positions of the rotor. When the rotor is in the angular position, $\alpha = \pi$, shown in Fig. 15, the damper winding, $D\, D_1$, is at right angles to $A\, A_1$ and consequently, is unaffected by the current in $A\, A_1$ or $P\, P_1$. Hence, at this position the generator acts as if it had no damper

winding and the maximum values of the i_a and i_1 are the same for both cases.

When the rotor is in the angular position, $\alpha = \pi/2$, the axis of the damper winding coincides with that of the armature winding. It is obvious from the previous analysis that the value of the armature current at this instant is equal to the total change in flux interlinkages of $A\,A_1$ divided by the coefficient of equivalent leakage self-induction of $A\,A_1$, with respect to the damper winding, $D\,D_1$. The current in the damper winding will likewise be equal to $i_a\,M_{ad}/L_d$

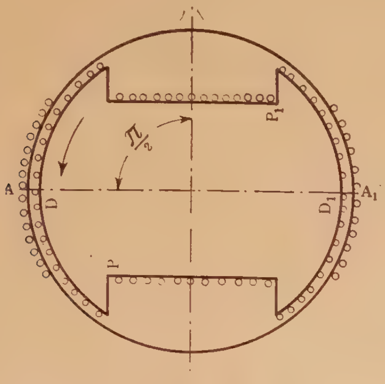


FIG. 16

$\alpha = \pi/2$

and will have its maximum value at this position. Since the field winding is at right angles to both of the other windings, there will be no mutual effect on it and the current, i_1, will be zero. That is, at $\alpha = \pi/2$

$$i_a = \frac{I_1\,M_{1a}\cos\alpha_0}{L_a - M_{ad}^2/L_d} \tag{15}$$

$$i_d = -\frac{I_1\,M_{1a}\cos\alpha_0}{L_a - M_{ad}^2/L_d} \times M_{ad}/L_d \tag{16}$$

$$i_1 = 0 \tag{17}$$

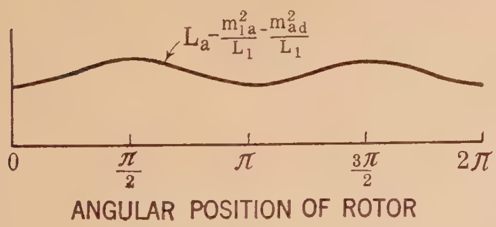


FIG. 17

At all other rotor positions both the field and damper windings act as secondary windings with respect to the armature winding, and the demagnetizing currents that flow in these two windings react on the current in the single-phase armature winding as those of a polyphase armature react on the field winding. The actual value of the coefficient of the equivalent leakage self-induction can be determined from the following simple mathematical relations.

$$i_a\,L_a + i_1\,m_{1a} + i_d\,m_{ad} = I_1\,M_{1a}\cos\alpha_0 - I\,M_{1a}\cos\alpha \tag{18}$$

$$i_a\,m_{ad} + i_d\,L_d = 0 \tag{19}$$

$$i_a\,m_{a1} + i_1\,L_1 = 0 \tag{20}$$

Solving these equations gives

$$i_a = \frac{I_1\,M_{1a}(\cos\alpha_0 - \cos\alpha)}{L_a - m_{a1}^2/L_1 - m_{ad}^2/L_d} \tag{21}$$

$$i_1 = -\frac{I_1\,M_{1a}(\cos\alpha_0 - \cos\alpha)}{L_a - m_{a1}^2/L_1 - m_{ad}^2/L_d} \times M_{a1}/L_1 \tag{22}$$

$$i_d = -\frac{I_1\,M_{1a}(\cos\alpha_0 - \cos\alpha)}{L_a - m_{a1}^2/L_1 - m_{ad}^2/L_d} \times M_{ad}/L_d \tag{23}$$

The equivalent leakage self-induction coefficient $L_a - m_{a1}^2/L_1 - m_{ad}^2/L_d$ will be constant for all rotor positions if the two windings on the rotor are identical and have sinusoidal field forms, for the following relations would then be true:

$$L_1 = L_d,\ M_{ad} = M_{a1},\ m_{ad} = M_{a1}\sin\alpha, \text{ and}$$
$$m_{a1}^2 = M_{a1}\cos\alpha$$

Then

$$L_a - m_{a1}^2/L_1 - m_{ad}^2/L_d = L_a - \frac{M_{a1}^2\sin^2\alpha}{L_1}$$

$$- \frac{M_{a1}^2\cos^2\alpha}{L_1} = L_a - m_{1a}^2/L_1 \tag{24}$$

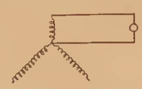
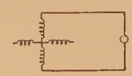
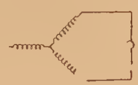
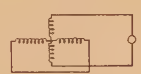
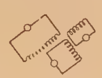
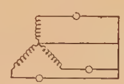
However, in actual salient pole machines the two windings cannot be made identical and consequently, the coefficient of equivalent leakage self-induction is slightly pulsating as shown by curve 1 of Fig. 24. Consequently, the damper winding decreases the coefficient of equivalent leakage self-induction of $A\,A_1$ at the intermediary positions. Hence, the effect of the damper winding at these intermediate positions is to increase the armature current and modify its wave shape, but does not effect the maximum possible value of the armature current.

Maximum Instantaneous Value of Short Circuit Current

In the case of polyphase alternating current generators, the maximum instantaneous values of the currents under short-circuit conditions can be determined from the general relations as given in equations (13) and (14) for single-phase generators, provided the necessary consideration is given to the mutual inductive effect of the respective circuits.

The data in Table I show the relative magnitude of the theoretical maximum possible values of short-circuit current delivered by alternating-current generators with different phases and winding combinations on the basis of a given field flux, for (a) constant armature wires per inch of periphery, and (b) constant terminal voltage.

TABLE I

Case	Phase	Winding Connection	Maximum Peak Value of Armature Current for Constant Conductors per Inch — Amperes	Ratio	Maximum Peak Value of Armature Current for Constant Terminal Voltage — Amperes	Ratio
1	1		$i_{a_{max}} = \frac{2 I_1 M_{1a}}{N_a}$	1.732	$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3 N_a}$	1.0
2	1		$i_{a_{max}} = \frac{2 \sqrt{2} I_1 M_{1a}}{2 N_a}$	1.225	$i_{a_{max}} = \frac{2 \sqrt{2} \sqrt{3/2} I_1 M_{1a}}{3/2 \times 2 N_a}$	1.0
3	1		$i_{a_{max}} = \frac{2 \times 3/2 I_1 M_{1a}}{3/2 N_a}$	1.155	$i_{a_{max}} = \frac{2 \sqrt{3} \times 3/2 I_1 M_{1a}}{3/2 \times 3 N_a}$	1.0
4	1		$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3 N_a}$	1.00	$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3 N_a}$	1.0
5	1		$i_{a_{max}} = \frac{2 \times 2 I_1 M_{1a}}{4 N_a}$	0.866	$i_{a_{max}} = \frac{2 \times 2 \sqrt{3/2} I_1 M_{1a}}{4 \times 3/4 N_a}$	1.0
6	2		$i_{a_{max}} = \frac{2 \sqrt{2} I_1 M_{1a}}{2 N_a}$	1.225	$i_{a_{max}} = \frac{2 \sqrt{2} \sqrt{3/2} I_1 M_{1a}}{3/2 \times 2 N_a}$	1.0
7	3		$i_{a_{max}} = \frac{2 I_1 M_{1a}}{3/2 N_a}$	1.155	$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3/2 \times 3 M_a}$	0.667
8	3		$i_{a_{max}} = \frac{2 I_1 M_{1a}}{3/2 N_a}$	1.155	$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3/2 \times 3 N_a}$	0.667
9	3		$i_{a_{max}} = \frac{2 I_1 M_{1a}}{3/2 N_a}$	1.155	$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3/2 \times 3 N_a}$	0.667
10	3		$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3 N_a}$	1.00	$i_{a_{max}} = \frac{2 \sqrt{3} I_1 M_{1a}}{3 N_a}$	1.00

$I_1 M_{1a}$ = flux interlinkages of one leg of a 3 phase armature winding due to the field current, when the axes of the field winding and the given leg of armature winding coincide.

$N_a = L_a - M_{1a}^2 / L_1$ = total equivalent leakage flux interlinkage coefficient of one leg armature winding and field winding when the axes coincide.

Effect of Saturation

In general, the iron part of the magnetic circuit does not have infinite permeability but is partially saturated at the condition of normal flux interlinkages. Since under the short-circuit condition which give maximum armature current a major portion of the flux interlinkages must traverse the leakage flux paths, saturation of the iron causes a decrease in the value of the induction coefficients and thus an increased armature current value for a given resultant flux interlinkage. This effect is apt to be quite pronounced at the condition for the maximum possible armature current for approximately double the normal flux interlinkages must traverse the leakage flux paths and the densities in the iron are necessarily extremely high. It is practically impossible to calculate the effect due to saturation on account of the complexity and indefiniteness of the leakage flux paths and distribution of the leakage fluxes.

Effect of Rotor Construction

In most practical alternating-current generators the rotating element is either solid or built up of reasonably thick laminations which are not insulated from one another, but are short-circuited by assembling rivets and bolts. Hence the iron of the rotor acts as an imperfect or unbalanced polyphase damper winding of high resistance and reactance. Part of this winding acts in parallel with the field winding and consequently, the values of the field current under short circuit will be less than was previously indicated for the thoroughly laminated rotor. This feature modifies the value of the maximum possible armature current only to the extent that it changes the leakage flux interlinkages of the rotor due to the secondary demagnetizing current. At the other rotor positions the values of the armature current are increased and the wave shape modified to a certain extent depending upon the effectiveness of the rotor material as a damper winding.

Effect of Resistance

If the resistances of the electric circuits are not negligible, Kirchhoff's Fundamental Law must be modified to take care of the changes in flux interlinkages that are necessary to overcome the $i\,r$ drops of the respective circuits. For instance, in case the armature circuit only has an appreciable resistance there must be a change of its flux interlinkages at any instant proportional to the $i_a\,r_a$ drop. Then referring to the armature current wave under the condition for maximum possible short-circuit current, the total change in flux interlinkages due to the $i_a\,r_a$ drop at the instant of maximum possible current is proportional to $K\,t_0\,i_{a_{max}}\,r_a = \int_0^{t_0} i_a\,r_a\,d\,t$, where K is the ratio of the average to the maximum $i_a\,r_a$ drop. Then applying Lenz's Law it follows from the previous analysis that the total equivalent leakage flux of the armature circuit plus the change in flux interlinkages required to offset the $i_a\,r_a$ drop must equal the total change, due to rotation, of its initial flux interlinkages. That is, for the single-phase generator

$i_a\,(L_a - M_{1a}^2/L_1) + K\,t_0\,i_{a_{max}}\,r_a = 2\,I_1\,M_{1a}$ or

$$i_a = \frac{2\,I_1\,M_{1a}}{(L_a - M_{1a}^2/L_1) + K\,t_0\,r_a}$$

$$= \frac{2\,I_1\,M_{1a}}{(L_a - M_{1a}^2/L_1) + K\,t_0\,r_a} \qquad (25)$$

Consequently, if the armature circuit has appreciable resistance, a resistance component must be added to the total equivalent leakage induction coefficient, and the maximum values of both the armature and field currents will be decreased.

On the other hand, an appreciable resistance of the field winding also results in a decrease in the short-circuit current values. In the case of a single-phase generator which is short-circuited at the instant of zero voltage or maximum flux interlinkages, the actual flux interlinkages of the field circuit are $I_1\,L_1 - \int_0^{t_0} i_1\,r_1\,d\,t$ at the end of the first half cycle. Consequently the total change (due to rotation) in the mutual flux interlinkages of the armature circuit is $2\,I_1\,M_{1a} - M_{1a}/L_1 \int_0^{t_0} i_1\,r_1\,d\,t$ instead of $2\,I_1\,M_{1a}$, as in the case when the field resistance is zero. The maximum values of the armature and field currents are,

$$i_{a_{max}} = \frac{2\,I_1\,M_{1a} - M_{1a}/L_1 \int_0^{t_0} i_1\,r_1\,d\,t}{L_a - M_{1a}^2/L_1}, \text{ and,}$$

$$i_{1_{max}} = \frac{2\,I_1\,M_{1a} - M_{1a}/L_1 \int_0^{t_0} i_1\,r_1\,d\,t}{L_a - M_{1a}^2/L_1} \times M_{1a}/L_1$$

If both circuits have appreciable resistance, the decrease in the maximum values of the short-circuit currents will be more pronounced. In this case the maximum current values are

$$i_{a_{max}} = \frac{2\,I_1\,M_{1a} - M_{1a}/L_1 \int_0^{t_0} i_1\,r_1\,d\,t}{(L_a - M_{1a}^2/L_1) + K\,r_0\,t_0}$$

$$i_{1_{max}} = \frac{2\,I_1\,M_{1a} - M_{1a}/L_1 \int_0^{t_0} i_1\,r_1\,d\,t}{(L_a - M_{1a}^2/L_1) + K\,r_0\,t_0} \times M_{1a}/L_1$$

HIGHWAY LIGHTING IMPORTANT TO NATION'S DEVELOPMENT

According to Robert P. Shaw, of the Massachusetts Institute of Technology, the scientific illumination of highways to take care of heavy traffic, to increase safety of travel, to reduce congestion and to spread the distribution of electric service is an important and necessary factor in our national development.

He says: "Is the agitation in favor of highway lighting based solely on the claim that it will benefit motorists? We believe that it is a factor in national development. Highway lighting increases night traffic and thereby relieves day congestion. It decreases running time and increases road capacity. It helps to bring electricity to the farm by providing a pole line. It increases real estate values by tending to extend the city along the highways and by bringing electrical conveniences. It costs one-tenth as much to light a highway as it does to replace mud by macadam. This is not an excessive expenditure for such an obvious public improvement."

ELECTRIFYING LIFE-SAVING BEACONS

The long life and sturdiness of the modern electric light, together with its brilliance and small cost of upkeep, is resulting in the gradual replacement with electric lamps of the oil lamps which have served for years to light the 5800 shore beacons and buoys that warn ships of dangerous rocks and reefs along the coasts of the United States. A standard battery and electric lamp has been developed by the government that will last for one year, with a maintenance cost of \$20, as compared with the \$15 a month paid for the cleaning, filling and lighting of an oil lamp. One man in a small motor boat can care for a large number of these electric signals, whereas a lighthouse tender and crew were needed to carry stores of oil or acetylene for the earlier type of lights. Where regular attention cannot be given to an electric beacon, automatic equipment is used whereby a new lamp is snapped into position in the event of the failure of the first one, and "sun valves," which turn the electric light on and off according to the brilliance of the daylight, have been brought to dependability.—*Electrical World*, May 24, 1924, p. 1105.

A New Self-Excited Synchronous Induction Motor

BY VAL. A. FYNN

Fellow, A. I. E. E.

Consulting Engineer and Patent Advisor, St. Louis, Mo.

THE advantages and disadvantages of synchronous motors are well understood. Broadly speaking, such machines have a poor starting and good operating characteristic. They can be made to operate at almost any desired power factor but are not always free from "hunting" and come to an abrupt stop when overloaded. It is not easy to secure high overload capacity together with high weight efficiency.

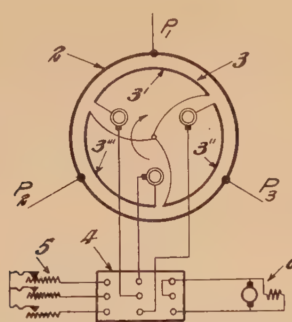


FIG. 1—SEPARATELY EXCITED SYNCHRONOUS INDUCTION MOTOR DANIELSON, 1901

Asynchronous motors, on the other hand, start readily with ample torque, operate steadily at all loads, exhibit a very high overload capacity and weight efficiency but show a somewhat low power factor, particularly at fractional loads.

Under these circumstances, it is not surprising that early efforts should have been made to combine the characteristics of these two types, but it was soon discovered that a commercial solution along these lines was not to be readily secured. All efforts appear to have centered on devising a suitable combination of elements of the synchronous with elements of the asynchronous motor. It is believed that the first synchronous induction motor was conceived and built by E. Danielson in 1901. This machine is diagrammatically illustrated in Fig. 1 and is separately excited. The first self-excited synchronous induction motor was probably produced by the writer and is diagrammatically illustrated in Fig. 3.

The principal points of interest in connection with any synchronous induction motor are starting performance, synchronizing ability, operation under normal loads and behavior under overloads.

The motor of Fig. 1 is built exactly like a three-phase slipring motor and starts as such, being synchronized and operated synchronously by injecting a unidirectional current into the secondary after the machine has been brought up to a speed near the synchronous. The unidirectional current is derived from an independent d-c. exciter and part of the winding on the secondary is short-circuited in normal operation. The starting performance is that of an asynchronous slipring motor and calls for no comment.

When the unidirectional current is injected into the secondary, the ampere turns it creates react with the synchronously revolving flux F' set up by the polyphase primary and produce a torque in addition to the induction motor torque. The latter can bring the machine close to synchronism but cannot synchronize it because it becomes zero at synchronism. Just prior to synchronization the secondary "slips" with respect to F'. The axis of the unidirectional ampereturns is fixed with respect to the secondary and therefore also "slips" relatively to the axis of F', with the result that the direction of the additional torque keeps changing.

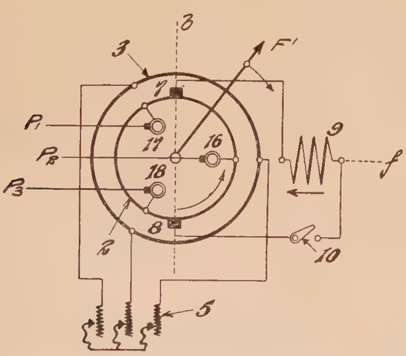


FIG. 3—SELF-EXCITED SYNCHRONOUS INDUCTION MOTOR. FYNN, 1906

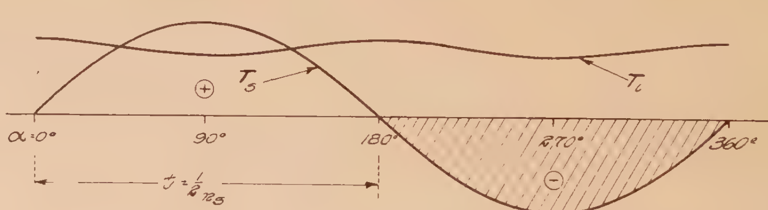


FIG. 5—INDUCTION MOTOR TORQUE T_i AND ALTERNATING SYNCHRONIZING TORQUE T_s NEAR SYNCHRONISM. DANIELSON, 1901.

Abridgment of paper presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924. Complete copies to members on request.

This torque alternates at slip frequency and has equal positive and negative maxima. Its maximum value is proportional to the prevailing maximum of F' and to the prevailing unidirectional ampere turns on the secondary. The curve T_s of Fig. 5 indicates how this additional torque changes with time. It is only the positive values of T_s which are available for synchronizing.

In synchronous operation the power factor of the motor of Fig. 1 can be adjusted by suitably adjusting the unidirectional excitation. No automatic means are provided to this end and the change in excitation required to keep the power factor constant from zero to full load is very great because of the large armature reaction and the small induction motor air-gap. When operating asynchronously, the secondary is the seat of the armature reaction but this is at all times equalled and opposed, *i. e.*, neutralized by corresponding primary ampere turns; the primary also supplies the true and practically constant excitation. When the same machine is operated synchronously, the primary is the seat of the magnetization $A\ R$ produced by the armature reaction and the magnitude of the unidirectional magnetization F on the secondary determines the maximum synchronous torque and the power factor of the machine. The vectorial sum of $A\ R$ and F is always equal to the necessary resultant motor magnetization R, the magnitude of which is determined by the magnitude of the necessary primary back e. m. f. Theoretically, when F is zero the motor current lags 90 deg. behind the terminal voltage and is alone responsible for R. When F equals the arithmetical sum of $A\ R$ and R, then the motor current leads the normal voltage by 90 deg. The operating values of F fall between these limits and the higher the excitation, the higher the power factor of the machine, provided a 90-deg. lead is looked upon as the highest power factor.

When the torque demand exceeds the maximum synchronous torque of the motor of Fig. 1, the latter falls out of step, lapses into asynchronous operation and pulls up almost immediately. The reason for this occurrence is the fact that the alternating synchronizing torque reappears as soon as synchronism is departed from. The negative values of this synchronizing torque have to be met by the induction motor torque, with the result that only the difference between the maximum induction motor torque and the maximum negative synchronizing torque is available for dealing with the load. One is faced with the unfortunate condition that the higher the synchronizing torque, the less the maximum available asynchronous torque. Yet, unless the synchronizing torque is equal to the maximum synchronous torque and the asynchronous torque is not interfered with, the active material cannot be utilized to the best advantage.

Turning to the prototype of the self-excited synchronous induction motor shown in Fig. 3, this is designed like an inverted polyphase slipring motor with some added elements. The primary is on the rotor and adapted to be connected to the supply by means of slip rings, but is also connected to a commutator with which co-operate brushes 7 and 8 connected to the exciting winding 9, located on the secondary in an axis displaced by 90 electrical deg. from the axis of the brushes 7 and 8. The secondary also carries a polyphase winding 3 connected to starting resistances 5. The motor starts exactly like the Danielson machine, but the excitation is taken from the commuted winding on the primary by means of the brushes 7 and 8. The brush voltage is always of slip frequency. When the primary is at rest, the brush voltage frequency is the same as that of the supply, when the primary runs synchronously, this frequency is zero and the brush voltage is unidirectional. The magnitude of this brush voltage depends on the magnitude of F' and on its speed with respect to that of the commuted winding on the primary. Since this speed is constant, the brush voltage is only dependent on the magnitude of F'. The primary revolves in a direction opposed to that in which F' rotates. When the primary is at rest F' revolves synchronously with respect to the stator and therefore to the brushes 7 and 8; when the primary runs synchronously, F' is stationary in space. The frequency of the brush voltage changes as the relative speed between F' and the axis of the brushes 7 and 8.

Near synchronism, F' moves with slip frequency with respect to the stator and therefore to the brush axis and to the axis of the winding 9. The frequency of the brush voltage is now very low and the brush current sent into the winding 9 may safely be taken to be in phase with the brush voltage. In the case of Fig. 3, the additional torque, that over and above the induction motor torque, is produced by the interaction of F' and the conduced ampere-turns in 9, due to the brush current conducted into that winding. When the brush current is zero, then the additional torque is zero. The brush voltage is zero whenever the axis of F' coincides with the brush axis. In a two-pole motor this occurs twice per revolution. The additional torque must also be zero whenever the axis of F' coincides with that of the winding 9, which also occurs twice per revolution in Fig. 3. Since the axis of 9 is perpendicular to the brush axis, the additional torque of Fig. 3 must be an alternating torque of double slip frequency, as indicated in Fig. 20 by the curve $T_{s,9}$ The positive and negative maxima are equal and proportional to 70 per cent of the maximum conduced ampere turns in 9 multiplied by 70 per cent of F'; in other words, to F' multiplied by half the maximum value of the conduced ampereturns on the secondary.

At synchronism, F is taken from the primary by means of the brushes 7 and 8. The exciter is in the form of a synchronous converter and is embodied in the motor itself. The fact that the exciter is integral with or built into the motor is important. It has already been stated that in any synchronous motor R is at all

times the vectorial sum of F and $A\ R$. Now the magnitude and space location of R absolutely determine the magnitude of the brush voltage, *i. e.*, of the exciting voltage in Fig. 3. At no-load $A\ R$ is very small, particularly when F is set to cause the motor to operate at about unity power factor, and R practically coincides with F. The direction of the latter is fixed in space and determined by the axis f of 9. As the load increases, $A\ R$ makes itself felt and the axis of R travels away from that of 9 in a direction opposed to the rotation of the primary 2. As the angular displacement between 9 and R increases, so does the brush voltage diminish. At light loads, when R is practically at right angles to the brush axis, all of R is effective insofar as the brush voltage is concerned and the latter is a maximum. At higher loads the angle between the axis of R and that of the brushes is less than 90 deg. and the brush voltage is correspondingly smaller. There is an inherent interrelation between motor load and exciting voltage, but the latter diminishes as the former increases.

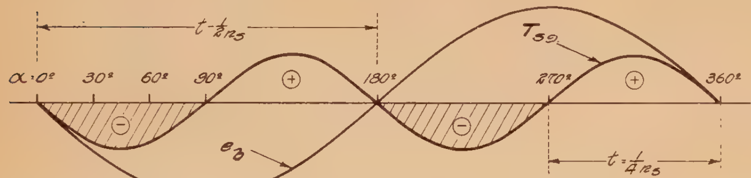


FIG. 20—SYNCHRONIZING VOLTAGE AND ALTERNATING SYNCHRONIZING TORQUE IN FYNN 1906 MOTOR

A synchronous operation under loads in excess of the maximum synchronous is interfered with by the reappearance of the additional alternating torque.

Notwithstanding all its fault, the motor of Fig. 3 possesses most of the elements necessary to a satisfactory solution of the problem, but it required considerable study to find just how the inherent qualities of this type of machine could be brought out and utilized to the full. It may be interesting to state that the author arrived at the complete solution here disclosed by the theoretical route and without a single experiment. In the same way he devised quite a series of synchronous induction motors which embody different and independent solutions of the several difficulties hereinbefore set forth. His several inventions in this field are held by two independent interests, one of which owns all but that covered by U. S. P. 1,337,648.

Fig. 21 diagrammatically illustrates one of the new motors in its two-pole form. The rotor is the primary member, it carries a polyphase winding 2 adapted for connection to the supply P_1, P_2, P_3 through the slip rings 16, 17 and 18 and a commuted winding 11 with which co-operate brushes 7 and 8 carried by the secondary member which is here the stator. The secondary carries an "exciting" winding 9, connected to the brushes 7 and 8 by way of the adjustable resistance 13 and displaced 90 electrical deg. from the brush axis, and a "neutralizing" winding 12 coaxial with the brush axis and connected to the brushes by way of the adjustable resistance 14. In addition, an adjustable resistance 15 is connected to the brushes 7 and 8 to shunt the commuted winding 11.

This machine can be operated with and without the resistance 15. Assuming that 15 is not used, the slip rings are connected to the supply with the circuits of the windings 9 and 12 open or closed over the rotor and a predetermined amount of resistance. The polyphase rotor currents produce F' in the usual manner and the latter generates secondary induction motor torque producing currents in the stator windings 9 and 12, displaced by 90 electrical deg. and therefore in the

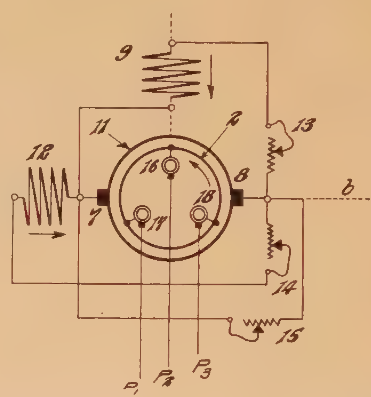


FIG. 21—SELF-EXCITED SYNCHRONOUS INDUCTION MOTOR. NEW FYNN

most favorable position for producing a uniform torque with F'. The secondary currents generated in 9 as well as in 12 close over the brushes and the rotor winding 11 and can be regulated by manipulating the adjustable resistances 13 and 14, whereby the torque developed and the current taken by the motor can be adjusted like in a slip ring induction motor. In this manner the motor reaches a speed very close to the synchronous. At such time F' moves with slip frequency with respect to the windings 9, 12 and the brushes 7 and 8. The slip frequency single-phase brush voltage sends a considerable current through the windings 9 and 12, and the secondary conduced ampere-turns thus set up in said windings, reacting with F', develop powerful additional torques. These additional torques, developed by the windings 9 and 12, which first did duty as polyphase secondaries of a polyphase asynchronous motor, bring the motor into step, producing a further change in the reactions within the machine. As soon as synchronous speed is reached, F' becomes stationary in space, the brush voltage becomes

unidirectional and the magnetizations produced by the stator windings 9 and 12 also become unidirectional. These magnetizations combine vectorially with the primary load reaction and replace F'.

Small machines can be started and operated without the use of adjustable resistances in the circuits of the

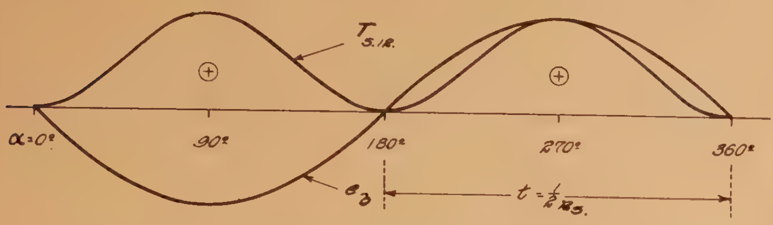


FIG. 37—SYNCHRONIZING VOLTAGE AND UNIDIRECTIONAL PULSATING SYNCHRONIZING TORQUE COMPONENT. NEW FYNN MOTOR

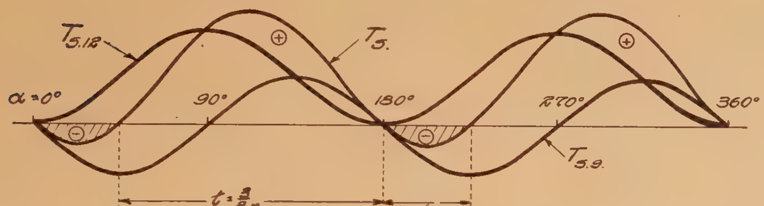


FIG. 38—RESULTANT SYNCHRONIZING TORQUE OF NEW FYNN MOTOR WHEN THE AMPERETURNS IN THE EXCITING AND NEUTRALIZING WINDINGS ARE ABOUT EQUAL

windings 9 and 12. For larger machines adjustable resistances should be used and reduced in one or more steps as the speed increases. For still larger motors, or when the starting conditions are particularly severe or the winding 11 operates close to the limit of good commutation, it is advisable to use the adjustable resistance 15 to shunt the commuted winding at starting. When the resistance 15 is used, its value should be increased with increasing speed and made infinite before synchronism is reached.

The additional torque $T_{s.9}$ resulting from the interaction of F' and the conduced ampere turns in 9, is of double slip frequency just like the corresponding torque in the author's 1906 motor, its configuration is shown in Fig. 20. But in Fig. 21 a third torque $T_{s.12}$ is produced and results from the interaction F' and the conduced ampere turns in 12, this is a strictly unidirectional and pulsating torque and its configuration is shown in Fig. 37. It is unidirectional because the brush axis coincides with the axis of the winding 12 instead of being at right angles to it. By making the ampere turns in 12 equal to or larger than the ampere turns in 9, the resultant synchronizing torque T_s becomes substantially unidirectional. When the ampere turns in these two windings are equal, the maximum amplitude of the negative wave of T_s is but 18 per cent of the maximum amplitude of the positive one, as shown in Fig. 38. This ratio is further increased in favor of the positive wave as the number of ampere turns in 12 is increased relatively to that in 9. Whenever the synchronizing torque is substantially unidirectional, *i. e.*, whenever its maximum negative wave amplitude is zero or but a fraction of the maximum positive amplitude, synchronization can be brought about under maximum synchronous torque without hunting and the asynchronous overload capacity of the motor is not interfered with. In other words, upon the demand of a torque in excess of the maximum synchronous torque of the machine, the motor will depart from synchronism but will continue to operate smoothly enough as an asynchronous motor, will show substantially the same asynchronous overload capacity as the corresponding slip ring induction motor, and will return to synchronism as soon as the torque demand has fallen a trifle below the maximum synchronous torque.

A desirable power factor regulating or compounding property is built into this machine by locating the axis of the exciting brushes at a suitable angle to the axis of the resultant unidirectional magnetization F of the secondary.

At no-load the axis of R can be made to nearly coincide with the axis of F. As the load increases, R will travel away from F in a direction opposed to the rotation of

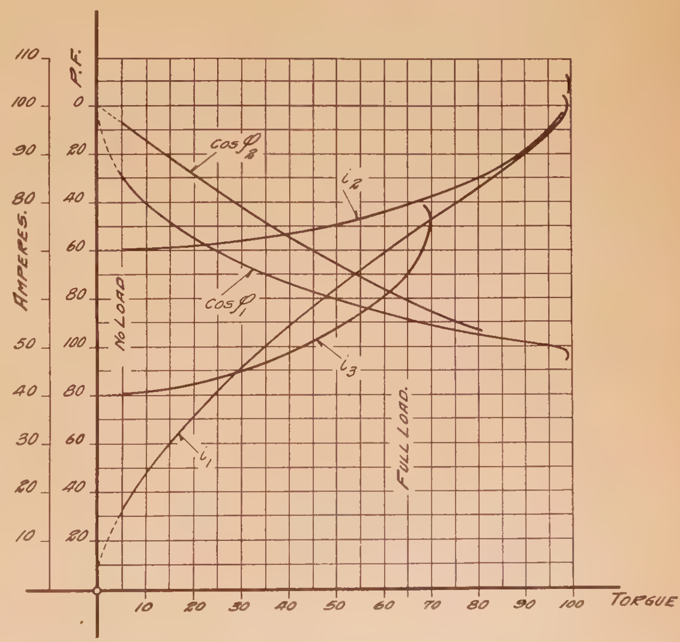


FIG. 45—COMPARATIVE PERFORMANCE CURVES OF NEW FYNN MOTOR AND OF A SYNCHRONOUS INDUCTION MOTOR WITH CONSTANT EXCITATION

the primary. Since the magnitude and space location of R determine the magnitude of the brush voltage and therefore that of F, and since the latter should increase with increasing load, the ratio of ampere turns in 12 and 9 is chosen to bring the axis of F

close to that of 12 and the vectorial sum of said ampere turns is chosen to bring R close to F at no-load. At no-load the axis of R lies close to that of 12 and the brush voltage is much less than maximum, being at all times proportional to that component of R which is perpendicular to the brush axis. As the load increases, so does the angular displacement between R and 12 or R and F increase, thus raising the brush or exciting voltage and compounding the machine. The maximum exciting voltage is reached when R occupies a position at right angles to the brush axis.

Fig. 45 shows the synchronous performance curves of the new synchronous induction motor and the corresponding curves of a separately excited synchronous induction motor with the same maximum synchronous torque but constant excitation. The curves i_1 and cos. φ_1 show the line current and power factor of the new motor plotted against torque. The corresponding curves for the machine with constant excitation are i_2 and cos. φ_2. They speak for themselves.

It is interesting to note that *all* of the windings of the new motor are active at *all stages*. They are fully utilized during the starting and the synchronizing periods as well as during the synchronous or normal operation and the asynchronous overload period.

Several modifications of Fig. 21 are described in the original paper. The functions of rotor and stator can be interchanged without in any way changing the mode of operation.

CORRESPONDENCE

THE AMPERE TROUGH EXPERIMENT

To the Editor:

In your June issue p. 554, Messrs. Grover, Daz & Turnbull endeavored to make it appear that I had said in previous papers that during the self-produced motion in the classic Ampere trough experiment the inductance does not always increase.

I deny ever having said this; on the contrary, I have said in print long ago, and repeated it (this JOURNAL, Nov. 1923, p. 1197; see also p. 1195) in the closing discussion of my recent paper (which discussion the above authors knew about as they refer to it) that the inductance *increased* in a similar case in which many able physicists also gave the wrong answer when asked in which direction the movement would be. Making it appear that I had said something I had not said, is setting up a straw man in order to have something to knock down. That is not proper scientific discussion, and shows weakness of the opposition. The fact that the movement in this and other of my experiments is in the *opposite* direction to what many able physicists claimed, and to what most if not all of their students would claim (when not warned), is enough to show that there is something wrong somewhere in the way things had been taught. In my paper I showed cases in which the flux and inductance both *decreased.*

What I did say and still claim, is that the usually taught law that *only* such self-produced motions will occur in a circuit as will cause an increase of inductance, is a special case law and not the most fundamental one; nor is it a universal law, as it requires restrictions and limitations to be added to it (like "provided the m. m. f. does not change," or "provided there are no structural changes," like sliding contacts, that useful camouflage of our ignorance and mistakes; ibid. p. 1196) and this itself proves conclusively that the law is not universal, but must be "patched up" to meet each exception. My paper (this JOURNAL, Feb. 1923 p. 139) also showed that it was not the most fundamental one. Such restrictions and limitations leave us without any law outside of these limits, where very useful cases might perhaps be found. I am sorry for those students who are taught only our old traditions. I am not one of those who thinks we already know everything there is to be known about electricity.

One of the chief objects of my paper was to open up new possible fields of research which had been closed to us by our being hide bound to very old laws and traditions. Should this not be encouraged instead of opposed? About 500 years ago the "knowledge" that the earth was flat was changed, although strongly opposed, even by threats of the death penalty for the unorthodox; the wonderful recent developments in the structure of the atom, have shown us that we had been in error, and that the problem of the alchemist was not impossible, older teachings notwithstanding; Einstein has pointed out surprising errors in some of our old laws. With such revolutionary developments why should a re-examination of our electro-magnetic laws be so strongly opposed instead of being encouraged. Several experts in the new atomic theories have told me that some of the strongly opposed "heresies" in my paper are in accord with those atomic theories.

The above mentioned authors made a serious error in one of their experiments (at least if they were really searching for the true fundamentals) by having part of the return leads very close to the moving bridge wire. In the truly fundamental case these return wires should, of course, be practically infinitely distant, so as to eliminate their effects.

CARL HERING.

TESTS ON NICKEL ANODES

Nickel anodes, such as are used for replenishing the solution in nickel plating, have formed the subject of a recent investigation at the Bureau of Standards. The purpose was to determine the relative behavior of different forms of nickel, such as electrolytic, rolled, and cast nickel, in the solutions used for electroplating. A study was also made of the effect of impurities, both accidental and purposely added.

The experiments showed that the addition of a chloride to the solution caused all types of anodes to dissolve with a high efficiency. The chief difference in the behavior of the different types of anodes was in the uniformity with which they dissolved.

Technical Committee Annual Reports 1923-1924

TRANSMISSION AND DISTRIBUTION COMMITTEE

To the Board of Directors:

The increasing demand for electrical energy has made necessary the interconnection of present systems and the development of additional hydroelectric power projects. These new developments are in many cases at points remote from load centers, and the transmission problems involve distances, amounts of energy, reliability, and voltages for their economic transmission in excess of previous operating practise.

The insulator problem continues to be one of the chief sources of difficulty in overhead transmission, and although considerable progress has been made, both in the design and manufacture of suspension type insulators, there still remains room for additional investigation on the electrical and mechanical effects influencing leakage resistance, deterioration, etc. Some flash-overs of insulator strings are still unexplainable and research work is being done to try to determine the cause and cure of these flash-overs. The cause of the flash-over possibly has a bearing on many of the so-called lightning disturbances.

The successful automatic operation of oil switches with relay protection at voltages as high as 220 kv. is an accomplished fact and this prevents the damage to insulators on account of flash-overs. It may be said that the transformers and switches operate satisfactorily at these high voltages. The improvement of the insulation to prevent flash-overs and many of the so-called lightning disturbances seems necessary, as the flash-overs do not seem to be caused by high-frequency or transient voltage, since the rise in voltage (sometimes double voltage) due to switching, does not of itself cause flash-overs. The mechanical stress, due to continued loading, vibration of aerial spans, temperature, humidity, and atmospheric conditions, in particular, require further study.

The result of experience this year on the 220-kv. transmission lines in California is very encouraging. In the northern and southern California systems 220-kv. transmission seems now an absolute necessity, as a result of the large power loads to be transmitted. The leading charging kilovolt-amperes supplemented by synchronous condensers is proving a valuable asset in voltage maintenance.

Transmission research work is being carried on in California and at other places, to determine all the factors entering into a system of transmission that will give the greatest practical reliability of service and the greatest stability and efficiency. Those responsible for financing and cooperating in carrying out this work are to be commended.

In the eastern section of the United States, various companies have, or are contemplating, changing their distribution systems from 3-wire 3-phase 2300-volt, or ¼ phase, 2300-volts, to 3-phase, 4-wire, 2300-4000-volt. The special problems involved in such change-overs include, in general, arrangement of wires, identification of neutral wire and phase wires, transformer connection, re-winding motors, etc.

The increased demands for electrical energy in urban districts are likewise tending towards the use of higher distribution voltages in order that larger amounts of energy may be delivered more economically, and the congestion of overhead routes avoided. This increase of distribution voltages makes necessary the development more of economical and efficient types of lightning arresters, fuses, switches, and other protective apparatus.

The demand for rural service continues to be felt throughout the country, and types of construction and material economically suited for this service are being given careful attention. The low-load factor, in general, experienced in rural service has made advisable some form of transforming equipment which will reduce the core loss during light or no-load periods, and progress is now being made in the development of equipment for this class of service. Also research work is being done to see how much power can be used by the rural areas in different sections of the country.

Continued progress is being made in the work of standardizing materials used for aerial construction the economical principles of which are apparent to both the producing and consuming branches of the industry. In order that the benefits of such standardization may be realized, the consumers should, in so far as possible, use such standardized equipment, and the manufacturer should continue to cooperate in the production and improvement of these various types of material. Where manufacture has been stabilized, such standardization can be accomplished through the American Engineering Standards Committee.

Cable Research

The most important development during the past year has been the evidence that the cable specifications of the N. E. L. A. and the present Standards of the A. I. E. E. do not insure a satisfactory cable for the higher operating voltages.

This subject is now receiving attention from the manufacturers as well as from the users of high voltage cable and as a result of these studies, it is hoped that it will be possible: *First.* To make the necessary changes in manufacturing processes and materials so as to secure a satisfactory cable for operation at the higher voltages, and *Second.* To devise a method of testing high voltage cable which will determine its operating characteristics in advance of its installation.

The Cable Research Subcommittee is cooperating

with similar committees of other organizations in the development of the necessary tests and specifications for this purpose.

During the past year a 500,000-cm. single-conductor underground cable installation has been made from the Sherman Creek Station of the United Electric Light & Power Company in New York City northward a distance of about eleven miles into Westchester County, which is intended for operation at 44 kv. 3-phase. An eight-mile line of similar size has been installed by the Cleveland Electric Illuminating Company for operation at 66 kv. 3-phase. These are the first high-voltage single-conductor underground transmission lines to be installed in this country and the results of their operation will be watched with considerable interest.

The committee is cooperating with the technical colleges in connection with their researches into the properties of impregnated paper insulation, as follows:

Massachusetts Institute of Technology.
  The effect of heat on impregnated paper insulation.
Harvard Engineering School.
  Dielectric loss and ionization.
Cornell University.
  Dielectric loss, ionization and the mechanism of cable failures of impregnated paper insulation.

Similar investigations are now under consideration by Washington University (St. Louis, Missouri).

Frank G. Baum, *Chairman.*

LIGHTING AND ILLUMINATION COMMITTEE

To the Board of Directors:

Pursuant of the recent practise, the report of this committee is submitted in two principal sections; the first being an outline of the committee's plan and work, and the second a brief resumé of the advance in lighting for the year.

Committee Activities

The Committee held an investigation meeting at the A. I. E. E. Headquarters, October 11, 1923, in which the plans for the year were generally formulated. Mr. Skiff was reappointed in charge of Illumination Items, and Dr. Shackleford in charge of solicitation of convention papers.

Various plans were discussed, and it was understood that the Chairman would continue the discussion among the membership of the committee by correspondence.

Illumination Items. The Committee has kept the Editor of the Journal continuously supplied with articles for inclusion in this section. Some of these are original contributions, others are reviews of papers or reports published elsewhere. Concerning the latter, it often happens that information of value to practising engineers is accompanied with much mathematics or involved discussion of theory. The committee has endeavored to extract the essential conclusions and data in convenient form for the use of the membership. Inquiries concerning various topics indicate that the articles are read with considerable interest.

In connection with this work the committee supplies the Editor with short notes, for use as fillers.

Convention Papers. The analysis of the situation by members of the committee, leads to the conclusion that it is not desirable at the present time to submit many papers on lighting at general conventions. Relatively little material of note, in the strict field of the committee, has come out in the past year.

It seems to be the general opinion, and that of the committee, that pure lighting practise papers are more suitable for the Illuminating Engineering Society. Most of the material of this sort is better suited for Illumination Items than for the convention programs.

Guided by these considerations, and the congested condition of convention programs, the committee has found it expedient to arrange for only one paper—namely an authorative treatment of the general subject of street lighting, which is being submitted for the June convention.

Lighting Publicity. It has been suggested by C. F. Scott, that the material published in Illumination Items was of sufficient value to warrant steps to encourage wider use. Several plans for encouraging the copying of Illumination Items have been investigated. The following procedure was finally adopted as the most expedient. The committee will sumbit to the Editor of the Journal, with each piece of copy a list of periodicals likely to be most interested. The Editor thereupon will secure a few extra proofs, and forward to designated publications, with memo of release date. It is expected, of course, that in using such material credit will be given to the Journal, as the source. This program is just being started, so that it is not yet practicable to judge how effective it will prove.

Cooperation with Sections. It has been the desire of the committee to cooperate with sections, to encourage and assist them in securing high-grade discussions of lighting questions.

No practicable way has yet been found for initiating such an activity on a large scale. However, a plan has been formulated for starting in to cooperate with college sections, under the direction of collegiate members of the committee. Owing to lateness of this development it was not found expedient to undertake this during the current year, and it is commended to the attention of next year's committee.

Designation and Scope of Committee. A communication has been received suggesting a change of name for the committee, and a definition of its scope.

This proposal is under discussion within the committee, and it is hoped to make suggestions in this connection before final action is taken.

Progress in Lighting and Illumination

Based upon the radical improvements in illuminants, there have for several years been many improvements

in lighting equipments, which have not been taken full advantage of in practise. Therefore, at the beginning of the Institute year, the development of lighting equipments was far in advance of their application. This was especially true of economic features, in that practise was far behind in taking advantage of the value available.

As a result of a growing realization of this condition, there has been a rapid accelleration in the application of improved lighting, in both new and revised installations; so that the year stands out as one of raising standards, successful commercial campaigns, etc., more particularly than as one of engineering development.

While this is regarded in the lighting industry as a commercial achievement, it is also interesting because it represents a growing tendency to apply good engineering principles to lighting practise.

As mentioned in last year's report, the sale of incandescent lamps provides the best numerical measure of the advance in extent and intensity of artificial lighting.

The sale in the United States of so-called large incandescent lamps for 1922 as reported last year was 203,000,000 a gain of about 22 per cent over 1921. The sale for 1923, is reported to be approximately 245,000,000, or a further gain of over 20 per cent.

These lamps are those used upon power circuits and as such are reported annually by the Lamp Committee of the National Electric Light Association to indicate the growth of that phase of electric lighting in which the central station industry is interested.

In addition, there has been growing up a very large use of lighting supplied by batteries and other sources, usually separate from central station lines, as for example, automobile lighting, flashlights, surgical lamps, etc.

Lamps for these services have been considered as a separate class, designated as miniature lamps. Previous information has been less complete and accurate with regard to these lamps. Last year's report carried an estimate that 85,000,000 miniature lamps were sold in this country during 1922.

More complete estimates now show that nearly 130,000,000 were sold in 1922. The latest compilation shows the sale for 1923 to have been approximately 175,000,000, nearly all tungsten. The remarkable extent of the lighting represented by miniature lamps has not been generally appreciated.

This is no doubt due to the fact that growth has been of such recent date. The earliest records now available are for the year 1908 when a little less than 2,000,000 miniature lamps, mostly carbon, were sold. The widespread use of electric lighted automobiles and of flashlights are the largest factors in this growth.

Illuminants. There have been no outstanding developments during the past year, though many minor improvements have been or are being made.

In the manufacture of incandescent lamps, the improved machinery referred to in last year's report has been further improved and more widely applied. Besides increasing the flexibility of adapting manufacture to meet the demand, these developments have shown an influence in reducing cost. It is reported that tungsten lamp prices are now at least 30 per cent less than in 1920, in spite of increased costs of labor and materials.

Last year's report also referred to the fact that it had been found practicable to make tipless lamps. This has now progressed to a point where practically all the more common types and sizes of tungsten lamps are being made without tips.

There have been a number of changes in filament form. For example, the 200-watt 110-volt lamp is now made with a ring-shaped rather than a saw-tooth or loop filament.

Bowl frosted lamps of the vacuum type have been widely used in open reflectors and shades for home lighting. When this finish was adopted an all-frosted lamp was considered extravagant, due to the loss of light through internal blackening of the bulb. Recent tests with various types of equipment in common use indicate that the all-frosted lamp is nearly as efficient. Where the bowl frosted lamp was used in connection with open reflectors and some styles of frosted globes, the filament was exposed to view. The all frosted lamps are therefore being recommended in place of the bowl frosted lamps in order to insure diffusion and better appearance.

In the focus type miniature lamps used for motor vehicle headlighting, an effort is being made to reduce the tolerance of dimensional variations, with the view of forming the basis of avoiding the necessity of refocusing upon replacement of lamps. The improvement should render practicable a fixed focus lantern. Such equipment if properly constructed, would do much to improve headlighting practise, which is today suffering from the failure of the motorist to focus.

Arc lamps have practically disappeared from all of the ordinary classes of lighting, with the exception of street lighting. In the ornamental form, a considerable number of arc lamps with magnetic electrodes are being used, especially in "white way" districts. It is reported that electrodes of increased efficiency have been developed during the year.

Arc lamps are, of course, still used extensively, for projection and photographic work.

Mercury arc lamps are used in photographic and industrial lighting and the quartz tube lamps for sterilization, fading and other chemical applications. No radical improvements have been reported.

The fact that the efficiency of present day illuminants falls far short of the theoretical ideal, is a continual incentive to investigators to search for improved methods of light production.

Much attention is being given to arcs and dis-

charges in gases. While some interesting experiments have been tried, no results giving immediate promise of practicability have been reported.

Lamp Equipments. There are a multitude of light-modifying equipments for use in connection with incandescent lamps. New types and improvements are continually being developed. Many of the improvements have to do with artistic appearance or mechanical convenience. No developments have been reported which incorporate radically new engineering principles.

The most distinctive development of the year is in connection with street lighting luminaires, following up the idea suggested by the recent highway lighting units.

Various characteristics of asymmetrical distribution have been incorporated in equipment for residence streets and thoroughfares, for the purpose of concentrating more light in useful direction, and reducing the light where useless or undesirable. The problems involved are rather complex, requiring consideration of degree of redirection, as well as relative values of light in different directions. There is still considerable difference of opinion as to what is most desirable in various classes of streets, with and without foliage, and considerably more practical experience is necessary before a general agreement among engineers can be expected. It seems likely, however, that some degree of asymmetry of light distribution will be found desirable for certain classes of streets, while on the other hand, symmetrical distribution will predominate in others, for example, "white ways" and business streets.

Quite a number of new types of traffic signals has been developed both in those used for the control of traffic and those which simply warn drivers of busy intersections. The former group are practically all electric lighted. Owing to the recent improvements in electric equipment, a growing proportion of the warning signals are electric lighted, either from central station circuits or self contained batteries.

Lighting glassware by its very nature is subject to certain variations as to light transmission and diffusing qualities. Such variations affect both the efficiency and appearance of luminaires. These variations can be minimized by care in manufacture and in some cases by grading. This, of course, means additional cost, so that unless there is a criterion for evaluating superior glassware there will be a tendency of the cheaper products to predominate. An association of glass manufacturers has been making a study of the problem with the view of providing more suitable method of specifying the desirable characteristics.

Practise. Standards of lighting are advancing in practically all fields, notably homes, streets, stores, show windows, signs and schools. The improvements involve both higher levels and better diffusion.

Home lighting, involving as it does the elements of art and tradition, has been found a difficult problem for the illuminating engineer. Too often the application of modern incandescent lamps and higher levels has been rendered ineffective because the equipment has not been suited for the more brilliant and powerful light sources.

About a year ago, the shallow diffusing globe unit was found to provide a considerable improvement in kitchen lighting. This application found a remarkable acceptance, and under aggressive commercial campaigns, this practise has spread so that over 300,000 of such equipments are now reported to be in use. The indications are that there will be even greater activity in this field in the near future. Moreover, by educating the home-maker to the possibilities of good illumination, it seems likely to facilitate the improvement of illumination in other portions of homes.

From the humane viewpoint, it is important that hospital operating rooms be as well lighted at night as in the daytime. During the year a number of installations have been made which supply not only a high level of diffuse illumination but also light of a color approximating closely to daylight. This is reported to have advantages in identifying particular classes of tissue, and so facilitating accurate work on operations.

Certain athletic sports, such as tennis, have for years been carried on under artificial light. Artificial lighting has also been tried for baseball and football, but little has been heard of it after the first try-out. During the past year unusually good results have been reported in several games of each, the method of illumination being floodlighting.

Considerable experimentation has been carried on by the Government Air Mail Service, toward the improvement of airplane landing lights, field lighting and beacons for mail routes. Considerable advance is reported and new beacons are now being set.

For a number of years considerable interest has been shown regarding the question as to whether or not there is something related to light as music is to sound.

Most of the attempts along this line have been the projection in sequence of various light colors, in varying intensity, without definite form. Some experimenters have used the effect to supplement musical productions.

One development which has attracted considerable attention during the past year has employed colors in more or less indefinite form, without musical accompaninent. Another development along similar lines, but for which no musical analogy has been claimed, automatically projects interesting kaleidoscopic patterns on a screen.

Various surveys and tests of lighting practise have been made and reported. A very important and extensive test of industrial lighting is now projected.

Codes and Standards. The state of Massachusetts has adopted an industrial lighting code similar to the American Engineering Standard. This is the ninth

state to adopt such a code. The Pennsylvania Industrial Lighting Code has been revised.

Last year reference was made to the organization of a sectional committee of the American Engineering Standards Committee to consider the project of a School Lighting Code, under the sponsorship of the Illuminating Engineering Society and the American Institute of Architects, (the A. I. E. E. being represented). This project has been carried on by the sectional committee and is understood to be ready for the final action of the American Engineering Standards Committee.

Another lighting standard referred to last year is the project relating to colored signal lights for traffic and other purposes. This question, which has many ramifications, is understood to be still under consideration.

American Engineering Standard on Illuminating Engineering Nomenclature and Photometric Standards, under the sponsorship of the Illuminating Engineering Society is receiving preliminary study for revision and further coordination with the corresponding European Standards.

Educational. For a number of years leading lamp manufacturers have conducted courses in illuminating engineering and lighting practise for representatives of the lighting industry. The past year has witnessed a considerable increase of interest in this direction.

Arrangements have been made by the National Electric Light Association for a course to be conducted under the auspices of the Illuminating Engineering Society for the purpose of training illuminating engineering specialists for central stations. This is to be held in the summer and fall of this year and is to include visits to a number of the larger cities.

Another educational undertaking about to be launched by the National Electric Light Association is a nation-wide movement to teach better lighting of homes.

American success in improving the practise in lighting has attracted much attention abroad and many visitors from various foreign countries have come to study our methods. Recently, a group of eight engineers from European lamp manufacturers inspected lighting in the large cities as far west as Chicago, and studied the American practises. Lighting demonstrations similar to those established in this country during the last two or three years have been installed in London and Paris.

In the United States the demonstration method of teaching good lighting seems to be firmly established. Various types of portable demonstrations are used in connection with lighting lectures.

A notable permanent exhibit, covering the principal applications of incandescent lamps, is attracting considerable attention.

A cooperative street lighting demonstration, covering about one-half mile of street has been installed in Cleveland to show the effect of various heights, spacings, locations, types and sizes of street lighting units. This has proved very helpful to municipalities studying methods of improving their street lighting.

At the Illuminating Engineering Society Convention at Lake George, New York, in September, 1923, one of the interesting presentations, was the solution of a hypothetical street lighting problem, by eleven different engineers representing a number of viewpoints. A similar method is being applied to an office lighting problem with three contributors. The scheme seems to have possibilities of coordinating ideas on lighting practise.

The 1924 meeting of the International Commission on Illumination referred to in last year's report, is to be held at Geneva, Switzerland, Supplementing the usual reports, it is planned to have papers from various countries.

The United States National Committee will present a group of American contributions in this connection.

Research. That scientific research is still giving considerable attention to light, is evidenced by a few of the outstanding discoveries reported.

A new primary standard of light has been produced and described by Herbert E. Ives. While candlepower standards are carefully preserved in the form of incandescent lamps at several national laboratories, it is highly desirable that an accurate means of primary check be available lest there be a tendency over a considerable period of years for the standards to drift. The primary standards of the past have lacked accuracy of reproduction at the hands of different experts and under different local conditions. The new standard seems likely to insure greater accuracy in this connection.

An improved quality of transparent optical quartz has been reported as produced in a laboratory at Lynn, Massachusetts, by E. R. Berry.

The gap in the radiation spectra, between the infrared and the electric waves has finally been investigated, by E. F. Nichols and J. D. Tear.

It was the final victory of Dr. Nichols' useful life, and he passed quietly away while presenting his results in an address before the National Academy of Sciences.

Conclusion. The remarkable accomplishments of electric lighting, are all the more notable when it is remembered that this art is so new and that many of the original pioneers are still alive and in active service. It, however, has reached the age at which losses may be expected to be numerous.

It does not seem suitable to close this report without mention of those outstanding Americans who have concluded their valuable contributions in this field, namely, Louis Bell, Charles P. Steinmetz and Ernest L. Nichols.

G. H. STICKNEY, *Chairman.*

MARINE COMMITTEE

To the Board of Directors:

The committee was organized, subcommittees were appointed and the first meeting was held November 8th. Three subsequent meetings were held. A good portion of the time of the committee's members has been devoted to the work of the Sectional Committee of the American Engineering Standards Committee for Electrical Installation on Shipboard.

The shipbuilding industry, while slightly improved from a year ago, is far from normal. The activities of your committee can only be reflected in proportion to that industry and greater improvement is hoped for during the coming year.

Owing to the success attending past installations of electric motors on shipboard, it is now almost universally recognized that electricity will be the future power for ships' auxiliaries outside of machinery spaces for all vessels, for all auxiliaries in Diesel engine propelled vessels and a portion of engine room auxiliaries in steam vessels.

Perhaps the most important and urgent work of the committee is the licensing of engineers, electrical, for vessels. The ship owners and operators must continue to bear the expense of educating the personnel, as no steps has been taken by the licensing authorities to improve the present conditions and, furthermore, the licensing authorities have candidly stated they can see no necessity for a change, although your committee has labored earnestly with them and presented what was thought to be conclusive evidence warranting action in that direction.

Your committee realized the importance of some action to insure proper maintenance of electrical apparatus on shipboard. We believe the matter has been presented to the shipowners and operators in such a manner that they are also convinced that some changes are desirable and your committee proposes to continue its activities, until some relief is obtained. It is to be regretted that developments did not warrant the presentation of the paper on the subject at the November 1923, meeting of the Naval Architects and Marine Engineers, as anticipated.

The Power Apparatus Committee is preparing, and no doubt will complete next year, some definite detailed recommendations for the kind of current, type of apparatus and control for various auxiliaries for several types of vessels.

The depression in shipping and shipbuilding has not given the Propulsion Committee the opportunity expected to collect and compile data from electrically propelled ships. There have been a few Diesel electric ships completed during the past year and some data should be available in the near future.

The Publicity Subcommittee have issued several interesting articles relative to marine electrical installations.

The other sub committees on Standard Appliances, Historical, Radio, Wires and Cables, Interior Communication Apparatus and Editing have taken care of current work with nothing special to report.

The committee as a unit has worked harmoniously. The coming year will tax the committee with matters pertaining to the licensing of engineers and considerable energy will be require to have the Marine Rules adopted as an American Engineering Standard.

The committee is to be congratulated for its consistant efforts and achievements.

G. A. Pierce, *Chairman*.

INDUSTRIAL AND DOMESTIC POWER COMMITTEE

To the Board of Directors:

During the past Institute year this committee had charge of an Institute Session at the Midwinter Convention in Philadelphia where two papers on the "Electric Elevator" were presented followed by a very interesting discussion of this important topic.

The committee assisted the New York Section in arranging a meeting on "Electric Drive for Ventilating Fans" which was held in New York November 14th, 1923.

At the present time increasing interest is being taken in the application and control of motors for industrial purposes. Commercial motors are limited to relatively few types, but the control apparatus is capable of wide variations and in many cases control can be designed which will permit the use of a standard motor for most applications. The control system has, therefore, been receiving an increasing amount of attention, as it is realized that the success of many applications of electric drive depends upon selecting suitable control equipment.

Surface indications would lead one to believe that the type and variety of control is being greatly increased; the contrary, however, seems to be the case. As every art develops engineers at first solve each problem in a new way as standard apparatus is limited and it is necessary to broaden their experience; as these accumulating data are analyzed it becomes possible to group the various problems and develop apparatus which will take care of the more frequent applications. It is also possible to subdivide the problem into units which can be standardized, so that where special systems are necessary they can be assembled from standard units.

Control engineering is working in the second stage where standardization is becoming of increasing importance. To a very great extent, the unit parts of

control equipment are being standardized and a number of combinations is being eliminated as it is found that during the earlier developments of the art systems were listed with only minor differences. By consolidating similar systems of control, a number of combinations now listed as standard can be eliminated. This standardization is a direct benefit to the art, as it reduces the new combinations and new apparatus developed on customers' orders; it enables the customer to obtain prompt service; and it enables the apparatus to be produced in a more economical manner, thus reducing the first cost of the installation and making electric drive more popular.

During the past year there has been some interesting applications and some new apparatus placed on the market.

The following is a partial list of new applications:

Silk Spinner Drive—In Textile Mill

The first commercial installation of a three-motor automatic drive for combination spinning, doubling, and twisting machine drive was placed in operation during this year. Each one of the three decks is driven by a one-horse power vertical motor, all three of which are mounted on the same end stand of the frame and in the proper location to drive the spindle belt.

An automatic magnetic trip throws the feed rolls out of action when the power is shut off or when it fails, and a fly-wheel on the motor, which drives the upper deck, continues the twisting on this deck for a short period, after the lower deck stops, sufficient to take up the slack in the yarn and thus prevent kinking.

The feed rolls are driven by a gear from the upper deck motor, thus insuring a positive twist.

The method of drive practically eliminates all kinks and broken ends due to failure of power and shutting down of the machine and also insures a positive and uniform twist.

Individual Motor Drive for Cotton Card

The first commercial installation of an individual motor drive on cotton cards was accomplished this year. The installation consists of 63 of the latest type of cotton cards installed in a new cotton yarn mill, each driven with a 1¼ h. p. gear-connected motor, mounted as an integral part of the machine. Control is accomplished with a special combination of snap switches in one cabinet to give normal forward operation and reverse direction of the machine for grinding the card clothing. Stripping is taken care of by rope and sheave drive, direct from the motor shaft.

The method of drive insures freedom from specks, dirt or oily lint, usually present with the line shaft and belt method of drive.

Electric Elevators

During the past year, there have been a great many installations of passenger elevators in office buildings, equipped with automatic levelling devices. The leveling being accomplished principally through the medium of an auxiliary motor which drives the hoist rope sheave through a set of spur and worn gears.

There has also been developed, a system for automatically leveling the elevator car at floor landings without the use of auxiliary motor, use being made of the main motor operating at a slow speed when leveling and controlled automatically when running at this slow speed. When the operator desires to stop at a floor, he moves his car operating switch to the neutral point when within a given distance of the floor at which he wishes to stop and the controlling mechanism then functions automatically to slow down the main motor and bring the elevator car to practically a level with the floor sill.

Another system of elevator control has been developed and has just been put in operation which has been termed, the Signal Control. This control operates somewhat on the order of the automatic push button elevator in that a passenger desiring to go up or down from any given floor in the building, presses the push button for the desired direction and the first approaching car will then automatically stop at that floor without any action on the part of the car operator, providing the elevator car is not loaded to capacity. When the passenger has entered the car, the operator closes the door and presses a push button in the car corresponding to the ground floor or the top floor and the elevator automatically starts off and runs to the terminal landing unless stopped by another passenger who has pressed a button on another floor. The operator in the car, when asked to stop at a particular floor, presses the button in the car corresponding to that floor and the car then automatically stops at that floor. This signal control system is also designed to automatically open and close the hatchway doors and the car gate.

These automatic leveling and automatic stopping elevators, can be operated on either direct or alternating current, as the motive power is usually supplied from a small motor-generator set which can be driven by a d-c. or an a-c. motor. The generator end of the set always being direct current.

The cars of these elevators are now in successful operation at 600, 700 and 800 ft. per min.

There has also been developed and put in operation recently, a new type of worm gear traction elevator, consisting of a *V* groove traction sheave driven by two worms operating on one gear wheel. The two worms being mounted vertically and each directly connected to the armature of a vertical-type d-c. motor. The acceleration and deceleration of this type of winding machine when used with field weakening motors having a speed range of one to two or one to three, is remarkably smooth and rapid and is practically free from back lash.

Oil Well Drilling

One of the most interesting developments in the petroleum industry for many years is the Hild System of oil well drilling. This system is especially adapted for rotary drilling and makes use of practically standard "draw works" but introduces several features which have been previously lacking. The electrical equipment consists of two wound-rotor induction motors with suitable reversing controllers and regulating resistance, together with a gear unit which combines a speed reduction and a differential unit.

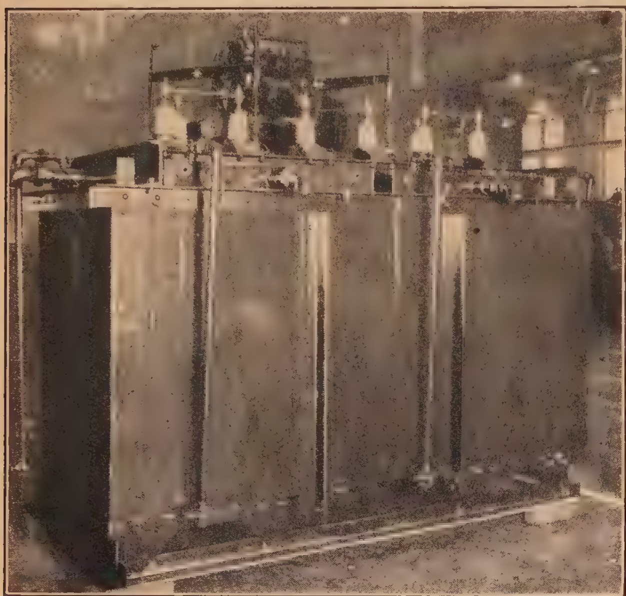


Fig. 1

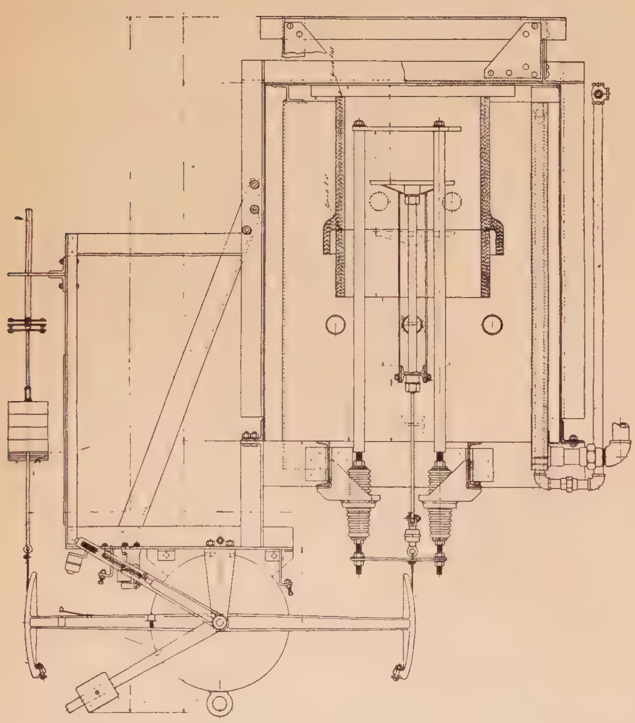


Fig. 2—Lewis Type Slip Regulator

This combination of motors, control and gears provides automatic feeding of the bit so that in sand or soft rock a high rate is obtained, while in hard or sticky formation the feed is slow, thus insuring a straight hold and reducing or eliminating the chances of twisting off the drill pipe. The forcing of the bit with no knowledge of the pressure on the bottom has probably been the cause of most of the trouble with rotary drilling; the Hild System eliminates this guess work.

Fig. 3—Safety Starting Rheostat for Slip Ring Induction Motor

Some of the new electrical equipment placed in service during the past year is as follows:

Slip Regulator. Figs. 1 and 2 show a 1500-h. p. slip regulator for a wound-secondary induction motor. This regulator is of the liquid type and differs from the previous regulators in the construction and arrangement of the cells constituting the resistor element for each of the three phases. These cells are located within the electrolyte tank and have the terminals of the stationary electro brought out at the top of the tank.

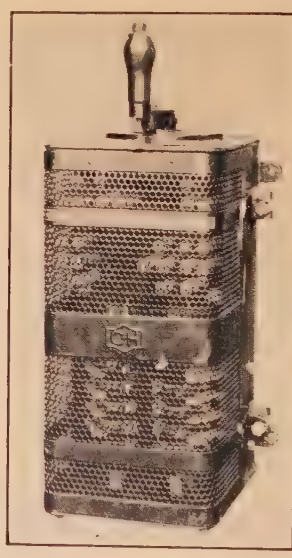


Fig. 4—Reversible Compound Drum Controller

This arrangement avoids leakage of the electrolyte, either through the connections at the bottom of the cells or by reason of failure of the cell walls.

Starter for Wound Secondary Induction Motors. This starter introduces resistance in the secondary of the

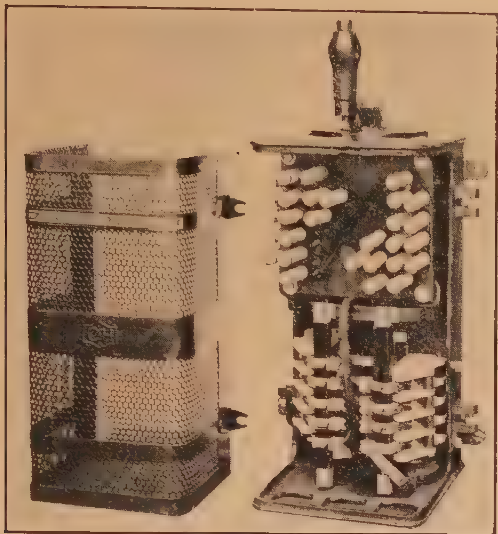


FIG. 5—REVERSIBLE COMPOUND DRUM CONTROLLER

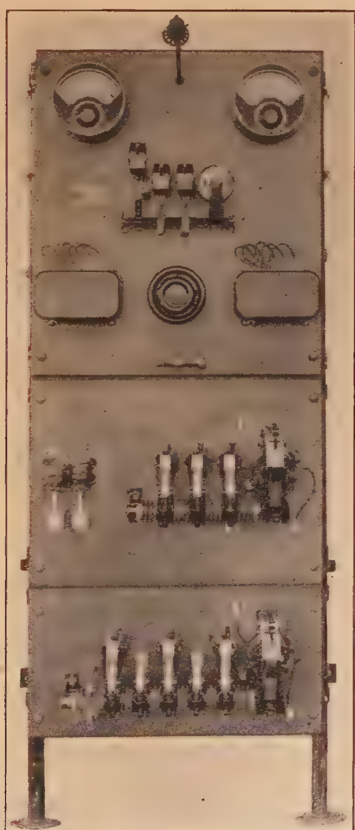


FIG. 6—AUTOMATIC STARTER FOR 3-PHASE SYNCHRONOUS MOTOR 150-AMPERES 550-VOLTS

motor during the starting period, its general features are illustrated in Fig. 3.

Machine Tool Control. The distinctive feature of this controller is the mounting of the field controlling resistors within the case and adjacent to the drum fingers for commutating it. Both the resistor units and the controller fingers connect to this resistor and are mounted on a single slate base; this eliminates lead wires. The resistor units can be removed by loosening

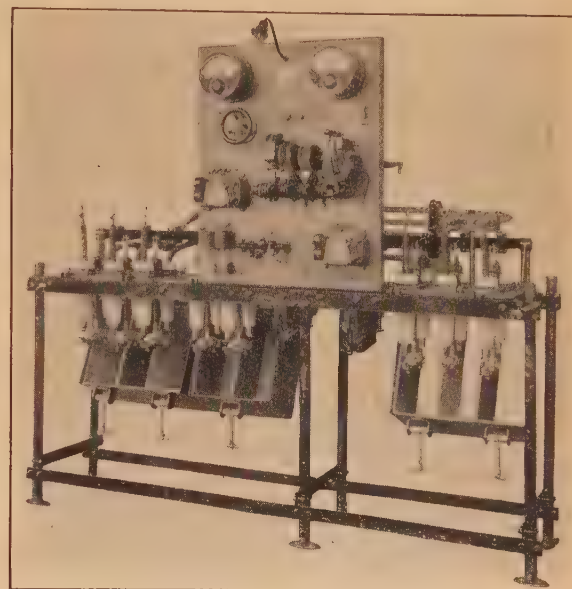


FIG. 7—AUTOMATIC SYNCHRONOUS MOTOR STARTER

one nut at the end of the stud on which they are mounted.

Synchronous Motor Starters. These starters somewhat resemble the auto-transformer starters used for squirrel-cage induction motors. A starter of the 550-volt class is shown in Fig. 6, and for 2200-volt service

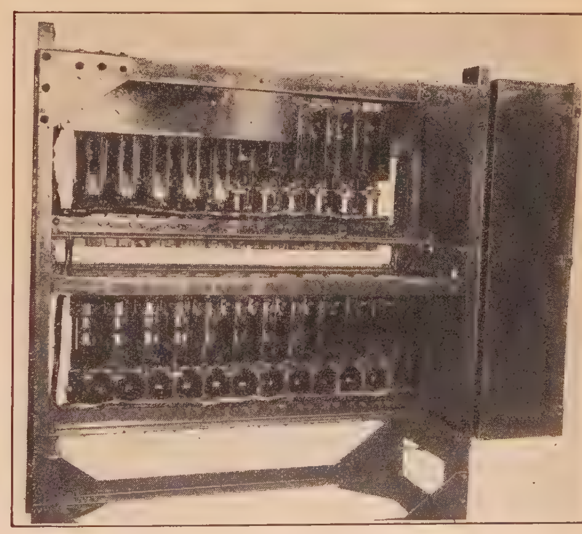


FIG. 8

in Fig. 7. The special features of these controllers are two motor-driven time relays, one for controlling the contactors which connects the motor to the auto-transformer to give reduced starting voltage, afterwards changing the motor connections to full voltage and the

other relay closes the field contactor after the motor has reached full speed.

Logging Donkey. The control illustrated in Figs. 8 and 9 uses pneumatic contactors for handling the main motor circuits. These particular controllers operated a 300/200 h. p., 2-speed yarding motor and two 250-h. p. loading motors. The illustration shows only one

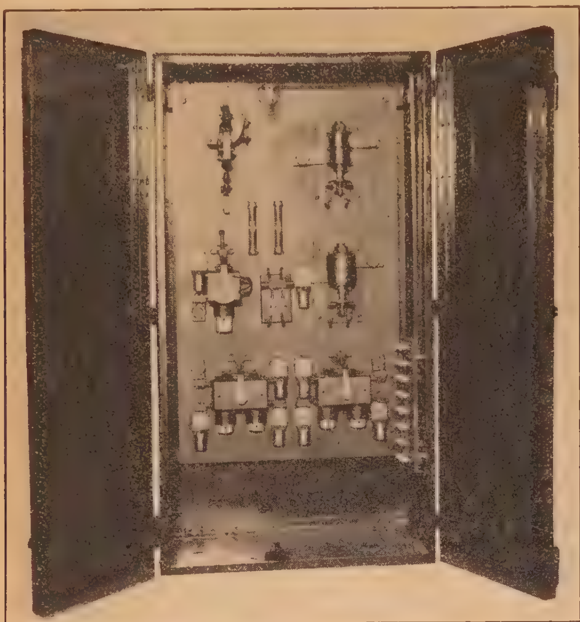


Fig. 9

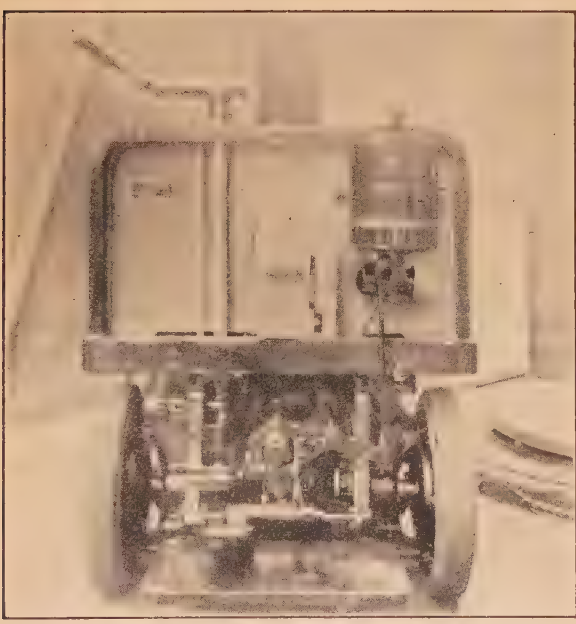


Fig. 10—Controller Mounted on Industrial Truck

controller. Air-operated contactors of this type are held open by a heavy spring and closed by and air cylinder. Their operation is still free from shock or jar and it is not necessary for them to be mounted in any definite position.

Industrial Truck. The control equipment shown in Fig. 10 is very interesting, not only from the apparatus standpoint but because it shows an application that is rapidly increasing in favor, namely, the storage battery. The control proper is of the drum-type, having mounted within the case a line switch interlocked with the brake pedal in such a way that the line switch is open if the operator applies the brake when the controller is in the running position. It is

Fig. 11—Plugs for Use with Safety Type Jack Disconnecting Switch

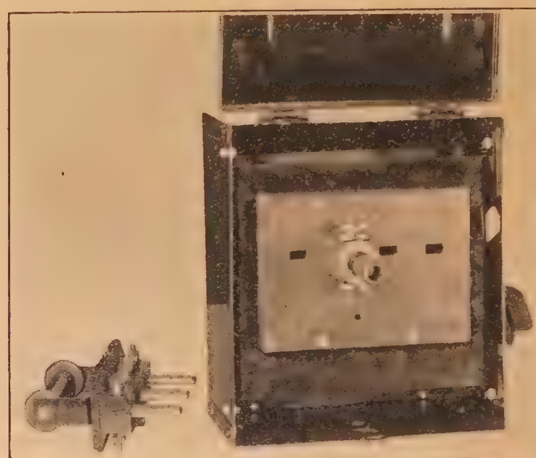


Fig. 12—Safety Type Jack Disconnecting Switch

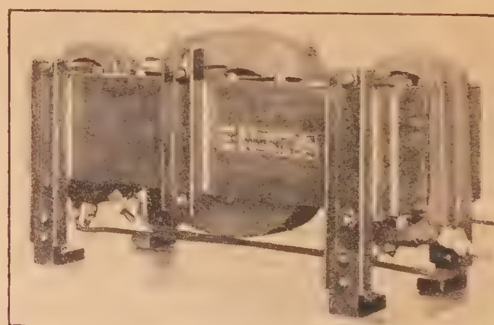


Fig. 13—Ten Kilowatt Magnetic Dimmer Element

then necessary to return the controller to the starting position before the line switch can again be closed.

Jack-Type Disconnected Switch. This device is illustrated by Figs. 11 and 12. The jack switch can be used for disconnecting control equipment and can also be used with ammeter and wattmeter jacks to connect these instruments in circuit without opening the line. Arrangements are made which permit this switch to be locked in the closed position, to prevent interference by unathorized persons.

Magnetic Dimmers. A three-wire dimmer of the

magnetic type is shown in Fig. 13. This device is similar to a transformer, the central coil being connected to a source of d-c. power; the outer coils are connected in circuit with the lamps to be controlled. The power delivered to these lamps is varied by changing the current in the d-c. coil, which changes the reluctance in the magnetic circuit of the a-c. coils. Fig. 14 shows the control plate for this magnetic dimmer.

Fig. 14—Magnetic Dimmer Control Plate

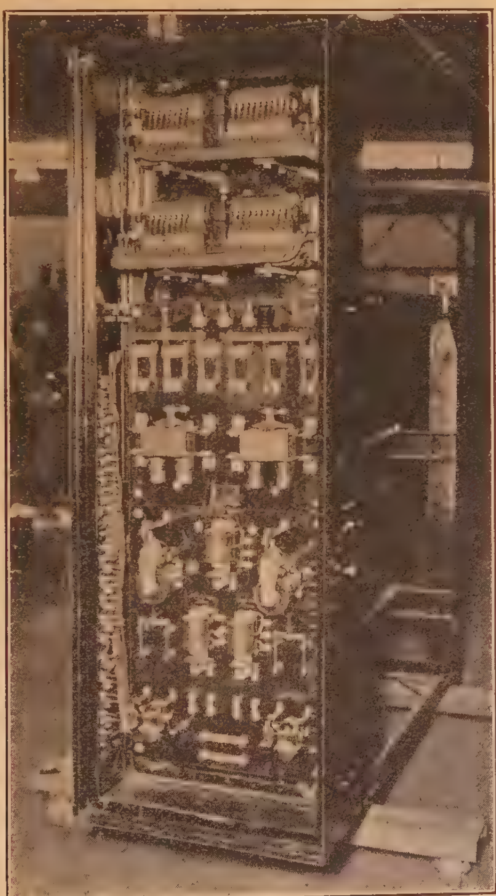


Fig. 15

A-C. Shovel. This is another application of the pneumatic contactor for industrial uses. This type of contactor was originally developed for railway service and is well adapted for industrial applications subject to continual vibration and shock. The design is made very compact and relatively light in weight. The electric shovel is similar to a large freight car filled with machinery; it is self-propelled and is often moved over rough and uneven surfaces. In many cases it is not practicable to operate the shovel with the floor level on account of the nature of the ground. The particular control illustrated is part of the equipment which

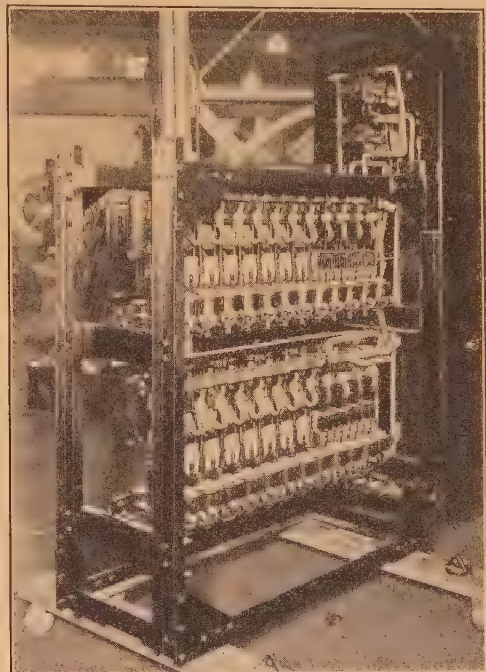


Fig. 16

Fig. 17—Enclosed Manual Motor Starter with Circuit Breaker

consisted of two 150 h. p. hoist motors, one 80-h. p. thrust motor and one 80-h. p. swing motor.

D-C. Selenoid Brakes. These brakes are of the standard shoe type, the braking pressure being applied by a single spring and released by a solenoid magnet. They can be adjusted by hand and are so arranged that

the proper position of the adjustment is indicated by a pointer on the brake arm. The brake coils are weatherproof and have type B insulation which will withstand high temperatures. The travel of the magnet core is short, which increases the life of the working parts.

Controller for Building Equipment. The controller illustrated in Fig. 17 consists of a line switch and a starting rheostat, both operated from the outside of the case. The rheostat arm is held in the "off" position by a spring, it is operated in the usual manner after the line switch is closed and is held in the running position by a magnet. The arm automatically returns to the "off" position when the line switch is open. The line switch is so arranged that only one pole is closed at a time. If a ground or short circuit existed during the closing period, one pole would be free to trip open and relieve the circuit at the time the second pole was closed.

Definite Time Accelerating Relay. This relay is designed to give a maximum interval of approximately five seconds and is for use on a-c. circuits. The principle of this relay is an armature energized by an alternating magnetic flux. This armature is drawn across the face of the magnet under spring pressure. Each time the magnetism passes through zero, the armature moves a small distance. The repeated moving and gripping of the armature by the magnetic flux results in a ratchet movement and introduces the desired time element.

H. D. James, *Chairman.*

ENGINEERING LITERATURE

(The Publication Committee in recent months has received a number of letters bearing upon the subject of the type of engineering literature which should predominate in the Journal. The only letters published have been those which favor an increase in the amount of highly technical and mathematical material. Several such letters have been published in the Journal in recent months. A letter from Mr. William J. Shore, here reproduced, is typical of the letters received which take an opposite view).

To the Editor:

A recent report of your Committee to the Executive Committee of the A. I. E. E., has just come to my attention and I heartily approve of the omission in the Journal, of highly theoretical and mathematical papers.

It has always seemed to me that these papers could be of interest to only a few select members, whose mental makeup was such, that the reading of highly theoretical and mathematical papers was no more of a mental strain to them than the reading of a daily newspaper is to me.

Naturally, under such circumstances, the Journal would not meet the needs and requirements of the vast majority of members of the Institute and in this respect we lose very much of its value as a medium of expression and interest to the members at large.

I do not wish to intimate or imply that the mathematical papers are of no value, but would simply like to emphasize the fact that the majority of members are unable through lack of mental capacity and business circumstances to take advantage of this material.

I trust you will appreciate the spirit which impels me to write this letter and hope that our publication in time will play a very important part in the activities of all our members.

William J. Shore

DISCUSSION

A PRECISE METHOD OF CALCULATION OF SKIN EFFECT IN ISOLATED TUBES[1]

(Dwight), Presented by Publication Only

L. F. Woodruff: The formula derived and presented by Mr. Dwight was first derived by Oliver Heaviside and published by him in the London *Electrician* for August 6, 1886 (p. 252). The article is reprinted in *Electrical Papers*, Vol. 2, p. 67. Heaviside's formula for the case of a circular tube in which the current distribution is not affected by the return circuit is given in his equation (**50b**), p. 69, and again in a different form in (**52b**) in the *Electrical Papers.* After changing, for purposes of comparison, from Heaviside's notation to that of Dwight, formula (**50b**) referred to reads

$$Z' = \frac{\sqrt{-j}\,\rho\, m}{2\,\pi\, r}$$

$$\frac{J_0(\sqrt{-j}\,mr) - \dfrac{J_1(\sqrt{-j}\,mq)}{K_1(\sqrt{-j}\,mq)}K_0(\sqrt{-j}\,mr)}{J_1(\sqrt{-j}\,mr) - \dfrac{J_1(\sqrt{-j}\,mq)}{K_1(\sqrt{-j}\,mq)}K_1(\sqrt{-j}\,mr)}$$

By definition,

$$J_0(\sqrt{-j}\,mr) = \text{ber}\,mr + j\,\text{bei}\,mr$$
$$K_0(\sqrt{-j}\,mr) = \text{ker}\,mr + j\,\text{kei}\,mr$$

From these equations a simple differentiation shows that

$$J_1(\sqrt{-j}\,mr) = \text{ber}'\,mr + j\,\text{bei}'\,mr$$
$$K_1(\sqrt{-j}\,mr) = \text{ker}'\,mr + j\,\text{kei}'\,mr$$

Making these substitutions in Heaviside's formula and dividing his value of Z' by the d. c. resistance R, equal to $\dfrac{\rho}{\pi\,(r^2 - q^2)}$, Dwight's identical formula (**10**) is obtained. Since ber and bei functions were not yet christened as such at the time of Heaviside's publication, he was constrained to use the more general J and K functions.

Heaviside also gives approximate formulas for large and small values of the argument.

The K function of Heaviside differs from the K function in the standard nomenclature at present used, in that his is the function of the real variable whereas the present K function involves the so-called imaginary argument. With present nomenclature, the following would be the definition of the ker and kei functions:

$$K_0(\sqrt{-j}\,mr) = \text{ker}\,mr - j\,\text{kei}\,mr$$

or

$$G_0(\sqrt{-j}\,mr) = \text{ker}\,mr + j\,\text{kei}\,mr$$

H. B. Dwight: Mr. Woodruff has given an appropriate and interesting reference in connection with the calculation of skin

1. A. I. E. E. Journal, Vol. XLII, 1923, August, p. 827.

effect in an isolated tube. The equation of Heaviside to which he refers applies to the case of two concentric tubes forming a return circuit. It may be shown by calculation that part of the expression for two concentric tubes is the same as the formula for the effective impedance of an isolated tube.

The solution for two concentric tubes by Dr. A. Russell, in 1909, (see reference 3 of my paper) was the earliest one to which I had access when writing the paper, and it gives four equations, each giving four unknown constants A, B, C and D which he states should be found by a long process of elimination. This is, however, not the best method to use when a good table of Bessel functions is available.

On reading over the descriptions by Heaviside in 1886 and Russell in 1909, it seems evident that they were chiefly interested in deriving formulas for very low frequencies and very high frequencies, which would not involve ber and ker functions, since a good table of these functions was not available at that time. These approximate formulas are long, and do not apply to the large intermediate range of frequency which is of most interest in practical applications, and so they can be considered as being almost superseded by the process of using the present large table of the functions ber x, ker x, etc., which table was first published between 1912 and 1916. It is interesting to note that, in drawing up a method using this large table, it is better to keep in line with the general form written by Heaviside in 1886, than the form written by Russell in 1990. The problem of an isolated tube should be worked out from the fundamental differential equation, as done in my paper, in order to show the formula for that case, as distinguished from the case of two concentric tubes.

The difference pointed out by Mr. Woodruff in the meaning of the symbol K representing Bessel functions of the second kind, is very important. In some books K corresponds to J and in others to I. This is an unfortunate state of affairs, since usually when a definition is changed, a different letter is chosen. It is especially unfortunate for electrical engineers, who cannot be expected to keep track of a fault of this kind in the naming of a mathematical function. A considerable number of the books and papers to which electrical engineers are accustomed to refer, use the older definition.

On page 173 of the book "Funktionentafeln" by Jahnke and Emde there is given an entire page tabulating the differences in the notations which have been used for Bessel functions of the second kind. In writing for electrical engineers, however, reference to this page would not be sufficient. It would appear necessary whenever using the letter K for this purpose, to follow the procedure used by Mr. Woodruff, by stating that there is more than one definition of K and by showing clearly which definition is being used.

The terms ker and kei, which can be used only in certain particular problems, are more satisfactory in this respect, since they have always had only one meaning, and I was able to write my paper using only these quantities.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

NOTABLE IMPROVEMENTS IN FOOT-CANDLE METER

Which greatly increase the usefulness of this handy little light-measuring instrument

The development of the foot-candle meter up through the past six years of its existence has followed closely the steps in the progress of the art of illuminating engineering. In 1917, when the meter was first brought out, the changing attitude of the public toward light was becoming increasingly evident, as people began to realize that there was a very wide gap between mere lighting and good illumination. In 1920, with the value of productive levels of illumination fairly well established, the foot-candle meter was being improved to adapt it to the new conditions. The upper limit of the istrument was increased from 25 foot-candles to 40 and a much better color match provided for measuring higher intensities of illumination and illumination which more closely approximates daylight, as secured from the more modern type lamp.

Just as tables of recommended illumination values have had to be revised upward again and again as accumulating experience has demonstrated the value of higher illumination levels, so has it been necessary again to increase the upper limit of the foot-candle meter scale. The latest type of instrument (Fig. 1)

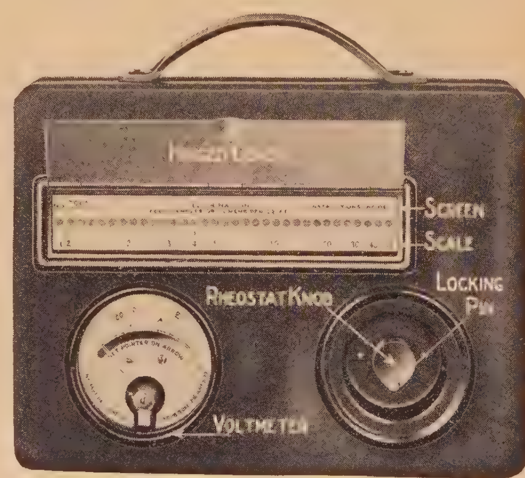


FIG. 1

will read any illumination value from twelve-thousandths of a foot-candle to one hundred foot-candles. It may be used equally well for measuring the illumination from street lighting equipment or the intensity in a well lighted show window. The color has been improved to the point where readings of daylight, or a mixture of natural and artificial light, in interiors can be made quickly and easily and with assurance of consistent results. Furthermore, these improvements have been effected in such a way that any existing meter can be adapted to the higher scale.

Those who are using these instruments every day as a tool in the sale of real lighting service will appreciate the greater utility made possible by the higher range instrument. The change has been made in response to a definite and insistent demand from users of the foot-candle meter who see the advantage of having their meters *leading* practise rather than *lagging behind it.*

World Power Conference and Other Meetings in London

The World Power Conference held in London June 30th to July 12th proved to be an exceedingly important and successful gathering of Engineers and others interested in the development, conservation and utilization of the power resources of the World.

The Conference was inaugurated by the British Electrical and Allied Manufacturers Association, in co-operation with numerous technical, scientific and industrial organizations. About forty countries were represented in the authorship of the four hundred or more papers presented. The following condensed classification of topics discussed will indicate the wide scope of the Conference: Power Resources, Power Production, Power Transmission and Distribution, Utilization of Power, and General —including Economic, Financial and Legal considerations, Research, Standardization, Education, Health and Publicity.

PRINCE WELCOMES DELEGATES

The Conference was opened on Monday afternoon, June 30th, with Lord Derby, as President, in the Chair. The Prince of Wales was introduced, and delivered an excellent address of welcome, in which he said:

"I feel this may prove the beginning of a series of Conferences whereby the combined knowledge and judgment of the World may be devoted to the solution of the many difficulties confronting not only science and research, but also economic progress throughout the World. International co-operation may emerge from the realm of the ideal into the realm of practical utilization, as the result of your deliberations, and I sincerely trust that full success will attend them."

Representatives of several countries responded. including Mr. Guido Semenza, President of the Italian Electrical Committee of the Conference, and Mr. O. C. Merrill, Chairman of the American Committee, whose address was heartily applauded, particularly when he said: "Mutual understanding is what the World needs most today, and to bring about that understanding it is contact between peoples as exemplified in this Conference, rather than between Governments that counts most heavily in the scale."

SCOPE OF THE CONFERENCE

It is not feasible to publish in the space available in the Journal, even a brief abstract of the papers—forty of which were scheduled for presentation by American authors, but it is planned to include all the papers, discussions and other proceedings of the Conference in four volumes, approximating 5500 pages, to be published by Percy Lund, Humphries & Co., Ltd., 3, Amen Corner, London, E. C. 4., price, if ordered before September 1, 1924, Ten Pounds, or, if ordered later, Twelve pounds. A prospectus of contents will be sent upon application.

The London Newspapers commented liberally upon the Conference, both editorially and in the news columns, the following quotations from the London Observer of July 6th being typical:

"The World's Power Conference at Wembly is an assembly such as never met before to deal with the fundamental problems of industrial civilization in the twentieth century. Forty nations are represented. No less than about four hundred papers are to be read throwing light upon resources and prospects in all parts of the Globe. An incomparable array of experts unite their thought and evidence. Many of the reports are elaborate treatises as large as books. In these cases only short summaries are as yet read and printed. But when all the papers are published shortly, the four great volumes which are to contain them will stand for years as a basic work of reference."

THE AMERICAN DELEGATION

About 175 American Engineers accompanied by approximately an equal number of members of their families attended the Conference. The largest single group of the Americans sailed from New York, June 19th, on the Cunard S S "Scythia" numbering nearly 200, including those who embarked at Boston the following day. There were 37 members of the A. I. E. E., accompanied by 36 members of their families on the "Scythia" including Messrs. John W. Lieb, Chairman, F. L. Hutchinson, Secretary, P. Junkersfeld, Chas. E. Skinner, and Calvert Townley, who had been appointed by President Ryan as the Executive Committee of the A. I. E. E. Delegation to visit the Institution of Electrical Engineers, in response to their invitation.

On board the "Scythia" the Engineers organized various Committees, including others in the passenger list, and numerous sports and social events were conducted with great satisfaction. The trip was exceedingly enjoyable and ended by arrival at Liverpool early Sunday morning, June 29th, whence a special train carried the passengers to London, arriving there Sunday afternoon.

About 75 other American Engineers, including 35 members of the A. I. E. E. also attended the various meetings and other events in London, and the following were included in the list of presiding officers for the sessions of the Conference: Messrs. John R. Freeman, John W. Lieb, Fred R. Low, D. S. Jacobus, O. C. Merrill, John Murphy, Joseph W. Roe, and Geo. Otis Smith.

SOCIAL FEATURES

There were numerous receptions, luncheons, banquets and other social features arranged by various organizations for the enjoyment of the visitors, and these afforded ample opportunity for renewing old acquaintances and making new ones.

The first of these events was the official banquet of the World Power Conference on the evening of June 30th, which was attended by about 800 Engineers and other members of the Conference. Lord Derby presided, and Mr. Samuel Insull was the American representative among the Speakers.

On Thursday evening, July 3rd, a banquet was given by the American Committee in honor of the delegates from other countries. About 500 were present. Chairman O. C. Merrill presided, and the address of welcome was given by Dr. Arthur T. Hadley, former President of Yale University; the other speakers included Messrs. P. J. Pybus, M. Kamo, Em. Uytborck, John Murphy, Henry J. Pierce, and A. E. Kennelly.

Friday, July 4th, was celebrated by many of the Americans by attendance at the Annual Independence day Dinner of the American Society in London. The Chairman was the Hon. Frank B. Kellogg, the American Ambassador. The privilege of attendance at this function was greatly appreciated by the visitors.

Monday July 7th was the date of the London Summer Meeting Dinner of the Institution of Mechanical Engineers, which was attended and greatly enjoyed by many of the Americans. Dr. William H. Patchell, President of the Institution presided. The speakers included Messrs. Elihu Thomson, John R. Freeman and Fred R. Low.

In addition to the above there were numerous other interesting and enjoyable events, some given by the National Committees of other countries, and many by the various Engineering organizations of England, including the Institutions of Civil, Mechanical and Electrical Engineers, the latter being referred to at greater length below.

KELVIN MEDAL TO ELIHU THOMSON

The Kelvin Centenary was celebrated July 10-11. The programme included the presentation of the Kelvin Medal to Elihu Thomson, at a Meeting held in the Great Hall of the Institution of Civil Engineers Thursday afternoon, July 10th, which was attended by a large audience.

The Medal was founded in 1914, principally by British and

American Engineers to commerate the achievements of Lord Kelvin. The award is made every three years by a Committee of the Presidents of the representative British Engineering Institutions, after their consideration of recommendations received from similar bodies in all parts of the world.

After the presentation by Sir Chas. L. Morgan, and the response by Dr. Thomson, Sir Richard T. Glazebrook presided, and the official delegates of numerous organizations presented their written addresses for publication later, and the ceremonies closed by the delivery of the Kelvin oration by Sir Joseph J. Thomson.

The Kelvin Centenary Banquet was held on Friday evening, July 11th, and was attended by about 300 Engineers and Scientists. The Rt. Hon. the Earl of Belfour presided and the other speakers were Sir Richard T. Glazebrook, Dr. Elihu Thomson, Prof. Luigi Lombardi and Dr. A. E. Kennelly.

OTHER NOTABLE MEETINGS AND EVENTS

Some of the other events of particular interest during the visiting Engineers' stay in London were the various Meetings and trips arranged by the Institution of Mechanical Engineers in connection with their London Summer Meeting July 7-9, the Meeting of the Institution of Civil Engineers July 8th, at which Dr. Elihu Thomson delivered the James Forrest Lecture, entitled "Electrical Progress and its unsolved problems," the *Conversazione* at the Royal Society on the evening of July 10th, and the final event on July 15th, namely the *Conversazione* at the Institution of Civil Engineers by invitation of the Institutions of Civil, Mechanical and Electrical Engineers.

High appreciation of the plans prepared by the various organizations concerned, and the effective manner in which they were carried out and for the generous hospitality bestowed, was expressed upon numerous occasions by representative visitors. The majority of the American delegations departed from London July 14th-15th, many to participate in trips to Switzerland, France, Italy, Norway, Sweden, as well as through England and Scotland. Some were to attend Engineering Meetings in other countries, including the International Management Congress and the Convention of the Electrotechnical Association in Prague, July 18-26.

Institution of Electrical Engineers

Extends Courtesies to Members of A. I. E. E.

The Institution of Electrical Engineers had arranged a particularly attractive programme for the entertainment of the visiting Electrical Engineers in London July 10-15. About a year previously the Institution had extended an invitation to the A. I. E. E. to send a delegation to London to participate in a special series of Meetings and other events. In response to notices published in the JOURNAL about 65 members filed their names and were designated by the President of the Institute as members of the delegation. They were accompanied by approximately an equal number of ladies of their families.

On Thursday, July 10th, there was a Reception for the visitors in the headquarters of the Institution, followed by a luncheon at the Hotel Cecil, and which was attended by about 300 Electrical Engineers and Ladies. Dr. Alexander Russell, president of the Institution was Chairman; a toast to "Our Guests" was proposed by the Llewelyn B. Atkinson, past-president of the Institution and the response on behalf of the visitors was made by Mr. John W. Lieb.

Friday, July 11th, was utilized for a visit to the British Empire Exhibition.

Saturday, July 12th, a special trip with many interesting and enjoyable features was taken to Cambridge University, where the Cavendish Laboratories were visited. Sir Joseph J. Thomson, Master of Trinity and Sir Ernest Rutherford greeted the visitors. The group was entertained at luncheon as guests of Trinity College. Later there was a Reception and Tea given by the Vice-Chancellor.

Sunday, reserved seats were provided for the Services at Westminister Abbey and St. Paul's Cathedral.

Monday, July 14th, the visiting Electrical Engineers and ladies were again the guests of the Institution of Electrical Engineers on an all day trip to Birmingham and Stratford-on-Avon. The Mayor of Birmingham gave a luncheon for the visitors and tea was served at Stratford-on-Avon.

Tuesday, July 15th, there was another all day trip to Chiswick and Windsor. Various stops were made at places of particular interest. Luncheon at Chiswick was by invitation of Lord Ashfield, Chairman of the Underground Electric Railways of London, Ltd

The outstanding social event for the electrical Engineers was the Royal Garden Party at Buckingham Palace Saturday afternoon July 5th. For the invitations the visitors were again indebted to the Institution of Electrical Engineers, who obtained this special privilege for their guests, who highly appreciated this exceptional opportunity of seeing the King and Queen; also the Queen of Spain and many other members of the Royal Families of Great Britain and other countries.

The above gives but a mere outline of the numerous courtesies extended by the Institution of Electrical Engineers to their guests, all of whom were loud in their praise of the delightful hospitality of their hosts. At the headquarters of the Institution and elsewhere, Secretary P. F. Rowell and his staff were untiring in their highly successful efforts for the comfort and enjoyment of all the visitors.

Another Addition to the Library Service

At the June meeting of the Executive Committee of the Library Board it was decided to adopt the policy of inter-library loans which is in use by the more important libraries of the country. The rules of the American Library Association for the conduct of inter-library loans will be followed.

This will make it possible for members to borrow, through local public or college libraries, books that are rare or unusual and that are needed in research work, and which are not available through our regular lending service.

Members who wish to borrow books of this character should consult the local librarian, from whom the request for the loan should come. If it is feasible to grant the loan, the book will be sent to the local librarian for a limited time. Transportation expenses and insurance will be charged to the borrower library, which must assume all responsibility for the safe return of the book.

Each request for a loan will be considered on its own merits, and granted if this can be done without undue interference with the rights of other members. Periodicals will only be lent under unusual circumstances; for example, when the desired article is too long to photoprint at reasonable cost. Books that are extremely rare and those that are in daily use will not be lent.

Borrower libraries will be required to keep these books in their buildings and not lend them for home use, as these books are not lent by the Engineering Societies Library to members who visit it.

Libraries wishing to borrow books should address the Engineering Societies Library, 29 West 39th Street, New York.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Many Unusual Attractions Offered by Pasadena Convention

An exceptionally good list of papers, a gathering of Institute pioneers, executives and prominent engineers, a special trip from the East and the scenic wonders of the West are the outstanding attractions of the coming Pacific Coast Convention in Pasadena, October 13 to 17. Much interest is already being shown in the excursion trip from the East in which the members will have an unusual opportunity for traveling together in a congenial party. More details about this trip are published elsewhere in this issue.

At the meeting talks will be given by the noted pioneers on some of the early problems and activities in the electrical industry and this is a rare opportunity which will be welcomed by many of the older members as well as the younger.

Some of the leading central-station executives of the country will give addresses at a special evening meeting and this is another distinctive opportunity of foremost interest.

The technical sessions will offer much timely information on such subjects as transmission, electrophysics, the industrial uses of electrical power, telephony, machinery and street lighting.

Some very important information on the latest advances in transmission will be discussed in a large group of papers by the engineers of the Pacific Coast where extensive studies and developments are now in progress. These will be ably supplemented and balanced by some of the most noted authorities in the East.

R. A. Millikan in a lecture on some of his latest researches in electrophysics will attract and delight a large audience as he usually does by his simple presentation of an abstruse subject. A noteworthy group of papers will also be offered by the associates of Dr. Millikan in the Norman Bridge Laboratory of the California Institute of Technology.

Engineers interested in the application of electrical power to industries will profit by the session on utilization. Papers will be presented on the use of electricity in such industries as irrigation, electrometallurgy, lumber mills, cement mills, iron and steel and mining. In the accompanying list are given the names of papers which are at present being considered.

The entertainment side of the meeting is being well cared for. There will be a dinner and dance Monday evening, a dinner at the California Institute of Technology on Wednesday evening, a special entertainment program Thursday evening and a banquet on Friday night.

Golf and tennis will be enjoyed and tournaments will probably be played.

Several trips by automobile have been arranged, one especially attractive trip being to Mt. Wilson where the observatory and Carnegie Institute may be inspected.

The local convention committee promises a week of pleasure to those who attend. During the present year Pasadena is celebrating its fiftieth anniversary and the committee plans to make this convention an outstanding event of the year. The committee is composed of the following: R. W. Sorensen, Chairman; O. F. Johnson, Secretary; J. E. MacDonald, Chairman of Program Committee; M. O. Bolser, E. E. F. Creighton, H. B. Dwight, E. R. Hannibal, C. R. Higson, W. C. Heston, C. W. Koiner, J. A. Koontz, C. A. Lund, F. W. MacNeill, S. G. McMeen, L. W. W. Morrow, E. F. Pearson and E. R. Stauffacher.

TENTATIVE LIST OF TECHNICAL PAPERS FOR PASADENA CONVENTION

TRANSMISSION

The Hysteresis Character of Corona Formation, Prof. H. J. Ryan and H. H. Henline, Stanford University.

Corona Losses between Wires at High Voltage, C. Francis Harding, Purdue University.

Corona-Loss Tests on 202-Mile, 220-Kv. Transmission Line, Roy Wilkins, Pacific Gas & Electric Co.

Corona Losses from Large Cables, J. C. Clark, Stanford University, and F. F. Evenson, Benson Lumber Co.

Heating of Large Aluminum Transmission-Line Cables, R. J. C. Wood, Southern California Edison Co.

Lightning, E. E. F. Creighton, General Electric Co.

Lightning and Other Transients on Transmission Lines, F. W. Peek, Jr., General Electric Company.

A New Type of High-Tension Insulator, H. B. Smith, Worcester Polytechnic Institute.

High-Voltage Line Insulation, A. O. Austin, Ohio Insulator Company.

Limitations of High-Voltage Transmission, H. H. Dewey and T. A. Worcester, General Electric Co.

Transmission at 220 Kv. on Southern California Edison System, (Composite paper by members of Southern California Edison Company.)

Section 1. *Description of System and Operating Experience*, H. Michener.

Section 2. *Protective System*, E. R. Stauffacher.

Section 3. *Economic Studies in Transmission-Line Design*, W. D. Shaw and C. B. Carlson.

Section 4. *Vibration of Conductors and Overhead Ground Wires*, J. M. Gaylord.

Section 5. *Location and Right of Way*, V. D. Elliott.

A High-Voltage Wattmeter, P. C. Clark and C. E. Miller, Stanford University.

Power Measurements at High Voltages and Low Power Factors, J. S. Carroll, T. F. Peterson and G. R. Stray, Stanford University.

Machinery

Large Steam-Turbine Generators, W. J. Foster, E. H. Freiburghouse and M. A. Savage, General Electric Co.

Operating Practise

Operating Features and Technical Problems Associated with Interconnected Systems, W. E. Mitchell, Alabama Power Company.

Research and Electrophysics

(The eight papers following are by members of Norman Bridge Laboratory of Physics, California Institute of Technology.)

Influence of Temperature on Photo-Electric Emission, R. C. Burt.

Collisions of the Second Kind, Stanislaw Loria.

Electric Currents Due to Fields Alone, S. S. MacKeown.

Electronic Orbits in Atoms, R. A. Millikan and I. S. Bowen.

Transfer of Radiant Energy to Free Electrons, E. C. Watson.

Electronic Emission under the Bombardment of Positive Ions, A. L. Klein.

A Magnetic Lens, W. R. Smyth.

A Complex-Quantity Slide Rule, J. W. M. Du Mond.

A Method of Obtaining Steady High-Voltage D. C. from a Thermionic Rectifier without a Filter, F. W. Maxstadt, California Institute of Technology.

Utilization

Electrical Applications to Irrigation Pumping, R. H. Cates, Southern California Edison Company.

Electricity in the Cement Industry, Mr. Arnold, Southwestern Portland Cement Co.

Electric Power Application in Fir Mills, J. L. Wright, General Electric Company.

Electricity in Mines, F. L. Stone, General Electric Co.

Contribution of Electricity to the Steel Industry, K. A. Pauly, General Electric Company.

Electrical Equipment of Consolidated Mining and Smelting Company's Zinc Plant, R. H. N. Lockyer, West Cootenay Power Company.

Electrometallurgical Applications, J. L. M. Yardley, Westinghouse Electric & Mfg. Co.

Telephony and Telegraphy

Guided and Radiated Energy in Wire Transmission, J. R. Carson, American Telephone and Telegraph Company.

Telephone Transmission Maintenance Practises, W. H. Harden, American Telephone & Telegraph Co.

Telephone Line Balance, L. P. Ferris and R. G. McCurdy, American Telephone & Telegraph Co.

Illumination

Street Lighting, R. D. Whitney, Syracuse University and Syracuse Bureau of Gas & Electricity.

The Route to Pasadena

The route for the Convention trip will be through Colorado Springs, Salt Lake City, Feather River Canyon, San Francisco, Yosemite and Los Angeles. It is probable that some special cars will be formed as far east as New York but the gathering point for the entire group will be Chicago.

The party will leave Chicago about the evening of September 26 and will travel via the Rock Island Railroad to Colorado Springs where one day and night (September 28) will be spent. Visits may be made to Pike's Peak, the Cave of the Winds, the Garden of the Gods, Manitou, and Cheyenne Canyon. On the 29th the party will view by daylight the scenery along the Denver and Rio Grande through the Rockies on the way to Salt Lake City. Arriving at Salt Lake City on the morning of September 30, there will be an opportunity for a drive along the mountain side overlooking the Great Salt Lake and a chance to visit the great Mormon temple and hear the mammoth organ at noon. Starting early in the afternoon of this day the train will pass through the Great Salt Lake and will proceed on the Western Pacific route through deserts of Nevada and through the Feather River Canyon in California on October 1, arriving in San Francisco in the evening.

Three days, October 2, 3 and 4, will be enjoyed in San Francisco and the neighborhood. The members of the party will be free to pass these days as they please, but for the convenience of those who care to attend, a number of trips will be scheduled. Probably trips will be taken on October 2 to the University of California, Berkeley and along the Rim Road. On October 3 trips may be made by railway to the top of Mount Tamalpais and down into the Muir Woods. On October 4 visits may be made to Golden Gate Park, the Cliff House, seal rocks, Golden Gate, Ocean Beach, the Presidio, Twin Peaks overlooking San Francisco, and Stanford University by the rim route overlooking San Francisco Bay on one side and the Pacific Ocean on the other.

The next four days will be spent in the Yosemite Valley. The party will travel from San Francisco to Merced on October 5. On the 6th the Hetch Hetcy Valley and its famous power station may be visited. On the 7th trips can be made to Mariposa to see the Big Trees and to Glacier Point, the best viewpoint of the Yosemite Valley and ridges of the Sierra Nevada Mountains. On the 8th the party will take in the views in the floor of the Yosemite.

Thus the party will arrive in Los Angeles on October 9 and here again four days may be enjoyed as desired. Among the trips which may be taken on October 9 will be those to "Movie Town," the alligator farm and the ostrich farm. During the next two days, the 10th and 11th, a delightful trip by special automobiles will be arranged southward along the coast to San Diego and across the Mexican border into Tia Juana. Fatigue on this trip will be avoided by short stops at a number of places en route, such as the orange groves of Orange County, Long Beach, several old missions such as San Juan Capistrano, La Jolla Beach, Coronado Beach and Hotel, and several other points of minor interest. On the 12th a visit will be made to Catalina Island, giving a view of the marine gardens through the glass-bottomed boats and a sight of the only group of fur-seals south of the Behring Sea.

This will bring the time up to the opening day of the Convention, October 13. During the meeting a number of delightful trips will be taken, including a visit on Thursday, October 16, to Mt. Wilson and the famous observatory.

The return trip from Pasadena may be made by any of several different routes according to the wishes of the individuals. Naturally many will want to return by the route which touches the Grand Canyon of the Colorado. A one-day side trip as a minimum to the Canyon may be taken in connection with this route. There are altogether 14 days available after the convention for travel before the expiration of the summer excursion rates, midnight of October 31.

REDUCED RAILROAD FARES

As to the cost of the trip, rather complete information was given in the June issue of the Journal, page 572. A general estimate may be made if it is stated here that the round trip rate from New York to Los Angeles, including stopovers and a side trip to the Grand Canyon, will amount to about $225 including a lower berth. The rates from points other than New York, of course, are different in accordance with the distance.

All members who think they will probably join or who are interested in a preliminary way in this excursion will confer favor on the committee in charge if they will kindly send word to this effect to Institute Headquarters, New York. More details of this excursion to the greatest sights in the world are available, upon request, to anyone interested.

The 1924 Annual Convention

AT EDGEWATER BEACH HOTEL, CHICAGO

The Fortieth Annual Convention of the American Institute of Electrical Engineers was held at the Edgewater Beach Hotel, Chicago, June 23-27, 1924. The attendance numbered about one thousand, of which about three-fourths was from outside of the State of Illinois. This formed a very representative gathering, as practically every state in the Union was represented. While the attendance has been greater at some of the former conventions it is doubtful if any other of the Institute conventions have exceeded this one in the scope and importance of its technical papers and the social and entertainment features which were provided.

The technical sessions were unusually well attended and a great deal of profitable discussion was brought out in regard to some new types of machines, high-voltage cables, new and proposed Institute Standards, metropolitan distribution systems, and automatic operation of stations and substations.

While regret was everywhere expressed at President Ryan's enforced absence, the conduct of the convention and the arrangements for entertainments, inspection trips, etc., were most efficiently handled by the local committee under the leadership of Vice-President R. F. Schuchardt. The Edgewater Beach hotel proved to be an ideal convention headquarters, and the management provided every possible facility for the convenience and pleasure of the guests in attendance.

Monday Morning

The convention opened on Monday morning with a welcome from Mayor Dever of Chicago, and this was to have been followed by some remarks by President Ryan. Unfortunately and to the deep sorrow of all members, President Ryan had been prevented from making the journey to the East by physician's orders. In commenting on this Vice-President R. F. Schuchardt expressed the sorrow of the convention and proposed the motion to send President Ryan a telegram of regret. Accordingly the following telegram was sent:

Professor Harris J. Ryan
Stanford University
California

The whole convention sends affectionate greetings and sincerest regrets that you are unable to preside at your own convention.

Later the following telegram was received in reply in President Ryan's own inspiring style:

I greatly regret that I cannot be present with those in attendance at the Fortieth Anniversary Summer Convention.

The extraordinary strides that civilization now is making would not be possible without an ever increasing wealth of electrical facilities.

The chief purpose of our Institute is to broaden and deepen the electrical understanding of all who come within its influence. The greatest of all landmarks of understanding encountered during the four decades of the Institute is that all things in nature have an electrical foundation

Unlimited opportunities and corresponding duties must therefore confront the electrical engineers at every turn. What they will accomplish and when, must depend henceforward upon the quality and strength of their aggregate mind. Such aggregate mind becomes the unerring faith of the individual by which he is guided aright in doing his part in the great electrical service that is now rapidly consolidating the mental and motor resources of the world.

Our conventions enlarge and improve our aggregate mind. Let us do all we can to make the most of them.

With hearty greetings to everyone.

HARRIS J. RYAN

Section Delegates' Conference

The meeting was then turned over to Mr. A. W. Berresford, Chairman of the Sections Committee, for the first business of the convention, the Sections Delegates' Conference. The earnestness and the enthusiasm of the delegates in discussing the various problems of the Sections and the Institute was a clear demonstration of their interest in Institute affairs.

President-elect Farley Osgood made an impressive address, touching on the excellent work of the Sections and pointing out what might be expected in the future. He referred particularly to the possibilities which are offered by Geographical District meetings such as the one held in Worcester in June of this year.

Mr. E. H. Hubert, Secretary of the Meetings and Papers Committee, outlined some ways in which the plans of Sections for securing speakers and papers might be facilitated. He mentioned the many sources of information which are available in the Institute and that the Meetings and Papers Committee might act as a connecting link between this information and the Sections which want it presented to their members.

There was considerable discussion on the character of speakers and papers which should be presented to Institute Sections. It was brought out that at some Sections no strictly technical papers were desired, while at others technical subjects were well received, though the manner of presenting the subject is the all-important factor.

District Meetings

In the afternoon the conference continued with discussion relating mostly to District Meetings. Mr. L. E. Pierce, who was chairman of the recent Worcester Meeting Committee, read a paper he had prepared on the meeting. Following this several speakers mentioned the success which the meeting had been, particularly as it allowed ample time for presentation of papers and discussion. It was thought that this District type of meeting should be kept on a high plane as regards quality of papers presented. It was thought that if such a standard is maintained authors would be quite as willing to present their papers at District Meetings as at national conventions. There was much discussion on the extent to which the District meetings might replace the national conventions. A committee was appointed to word a resolution suitably expressing the sentiments of the meeting with regards to this type of meeting and at a short evening meeting after the suggestions of this committee were read, the following resolution was adopted for submission to the Board of Directors:

RESOLVED: That the district or regional meeting, as evidenced by the recent procedure and accomplishment in District No. 1, holds possibilities which warrant the most careful consideration of its adoption as accepted Institute practise.

Further, that a special committee be appointed by the Board of Directors to study the possibilities of the regional or district meeting and to consider its development and its relations to established conventions.

This recommendation is made with a view to encouraging the production of high class papers, maintaining and raising the standards of the Institute, and allowing the fullest possible participation of the members in Institute activities.

District Prizes for Papers

Another important matter which was offered in the meeting was the question of the separate Districts offering prizes for papers. After some discussion two resolutions were passed making recommendations to the Board of Directors with regard to such prizes. The resolutions were as follows:

RESOLVED: That there should be instituted, in the opinion of this body, a first-paper prize and a best-paper prize in each District.

RESOLVED: That the District prizes be \$25 each and that they be offered by the national body of the Institute.

Expenses of Vice-Presidents' Visits to Sections

Another recommendation of importance was made to the Board of Directors dealt with the expenses of District Vice-Presidents' visits to the Section. A motion was adopted as follows:

RESOLVED: That it is recommended that the expenses for one visit each year by the Vice-President of each District to every Section in the District, be paid from the national treasury. (It is contemplated that such visits may be made on an itinerary which shall economize both time and expense.)

This visitation by the Vice-President, it was pointed out, is in addition to the annual District Executive Committee meeting. The expenses of the Section Chairmen and Secretaries to the annual meeting have already been authorized as payable from the national treasury.

Section Budgets

The desirability of budgeting, at the beginning of the year, the expenses of a Section was rather freely discussed. It developed that some of the Sections prepare and follow a budget rather closely while others found such a procedure unnecessary. Mr. R. B. Mateer, Chairman of the Philadelphia Section, told of the thorough budget system worked out for his Section and also of a study of unit costs which the Section is making. In speaking of Section expenses many Sections stated that their expenses were amply covered by the Institute appropriation, while others had to make assessments, which were not, however, burdensome. It was the general opinion that the present plan of appropriations was working out satisfactorily.

The next subject discussed was the desirability of having two delegates from each Section, the outgoing and ingoing chairmen, attend the annual meeting, their expenses to be borne by the Institute. A resolution was passed stating that it seemed desirable to have these two delegates at the meeting and that the Board of Directors be requested to consider the practicability of appropriating money to cover the additional delegate's expenses.

There was some discussion on the advisability of creating Section membership committees to cooperate with the Board of Examiners. No official action was taken, however, towards changing the present system of operation.

As a final subject on the program a resolution was passed recommending the formation of Program Committees in each Section. The motion was as follows:

RESOLVED: That it is recommended that each Section establish a standing committee to be known as the Program Committee, for the purpose of stimulating the preparation of papers and cooperating with the District and the National, Meetings and Papers Committee.

A more detailed report of this meeting will be published in pamphlet form and will be available on request to Institute headquarters.

Tuesday Morning

The President's address, which was scheduled to open the technical session on Tuesday morning, was omitted owing to the absence of President Ryan. This will be published in the JOURNAL in a future issue. The balance of the session was devoted to the presentation of the Technical Committee Reports. Some of these reports are included in this issue of the JOURNAL and the balance will be published in future issues as rapidly as space permits. The character of the reports this year was generally excellent, and besides reviewing the committee activities for the year most of the reports included a résumé of the advances in the art during the past year, which add greatly to their interest.

Electric Club Entertainment

During and after lunch on Tuesday the members were the guests of the Electric Club of Chicago which furnished a delightful entertainment program. This consisted mainly of musical numbers by the Duncan Sisters. This luncheon was chosen as the occasion to present to these two attractive sisters a silver electric percolator as a mark of the Club's gratitude for many contributions the sisters have made to the Club's pleasure.

President's Reception

Among those in the receiving line at the President's reception were President-elect Farley Osgood, Past-Presidents C. F. Scott, Bion J. Arnold, Louis A. Ferguson, Paul M. Lincoln, A. W. Berresford and F. B. Jewett, and Vice-President R. F. Schuchardt. The presence of the wives of some of these officers added much to the occasion. The reception was followed by a dance which continued until a late hour and was much enjoyed by all.

Wednesday Morning

On Wednesday morning two parallel sessions were held, Session A being devoted to automatic operation of stations and substations, and Session B to telegraphy and telephony and electrophysics.

Session A was called to order at 9:00 a. m. by Vice-President Schuchardt, after which Vice-President H. W. Eales took the chair. This session was under the auspices of the Protective Devices Committee, of which Mr. H. R. Woodrow is chairman. The Chairman then called for the presentation of the following papers which were abstracted by the authors except in the case of Mr. H. L. Wallau, in whose absence his paper was presented by Mr. Mackey of the Protective Devices Committee:

Automatic Stations for A-C. and D-C. Networks, by C. W. Place; *The Cleveland Heights Substation of The Cleveland Electric Illuminating Company*, by H. L. Wallau; *Automatic Substations for Supplying 1500 Volts D-C. to Suburban Railways*, by C. A. Butcher; *Automatic Motor-Generator Equipments on Edison Service of The Indianapolis Light and Heat Company*, by Herman Bany; *Operating Experience with Automatic Equipment on an Edison System*, by F. D. Wyatt; *Automatically Controlled Hydroelectric Generating Stations*, by R. J. Wensley.

This group of papers on automatic operation was discussed by Messrs. R. H. Earle, H. A. S. Howarth, W. H. Millan, J. L. Woodbridge (read by Victor Thelin), Victor Thelin, D. K. Blake, G. I. Wright, L. F. Harza, A. M. Garrett, A. C. Grayson, F. R. George, H. T. Porter, C. W. Place, J. W. Bishop, E. E. Woodward and F. C. Hanker.

Session B on Wednesday morning, which was under the auspices of the Telegraphy and Telephony Committee, Mr. O. B. Blackwell, Chairman, and the Electrophysics Committee, Mr. F. W. Peek, Jr., Chairman, was called to order at 9:00 o'clock by Mr. L. W. W. Morrow, Chairman of the Meetings and Papers Committee. The first paper of the morning was on *Selective Circuits and Static Interference* by Mr. J. R. Carson, and was abstracted by the author.

Vice-President J. E. MacDonald took the chair at this point and called for the presentation of the next paper, *The Transmission Unit and Telephone Transmission Reference Systems* by W. H. Martin, who gave his paper in abstract.

These papers were then thrown open for discussion and were discussed by Messrs. L. W. W. Morrow, J. D. Robinson, L. J. Peters and A. M. Wilson.

Following the discussion Chairman MacDonald called for the presentation of the next two papers on the program, which were *Sensitive Radio-Frequency Relay*, by George Lewis, and *The Transient Visualizer*, by H. M. Turner. The author of the former paper being absent, it was presented by title only, and Mr. Turner's paper was presented by Lieutenant Palmer. The papers were then discussed by Messrs. J. Slepian and J. R. Craighead.

The last two papers of this session were entitled *Temperature Rise of Stationary Electrical Apparatus as Influenced by Radiation, Convection and Altitude*, by V. M. Montsinger and W. H. Cooney, and *Effect of Altitude on Temperature Rise of Electrical Apparatus*, by R. E. Doherty and E. S. Carter. These papers were presented in abstract respectively by Mr. Montsinger and by Mr. Doherty, and were discussed by Messrs. W. J. Foster, E. B. Paxton, Louis B. Cherry and H. M. Hobart

Past-Presidents' Luncheon

On Wednesday the luncheon of Past-Presidents was thoroughly enjoyed. Although some of those who would have attended were in Europe at the time, the following representative group was present: President-elect Farley Osgood, and Past-Presidents C. F. Scott, B. J. Arnold, L. A. Ferguson, P. M. Lincoln, A. W. Berresford and F. B. Jewett.

All of the afternoons during the convention were devoted to inspection trips, sports and entertainments, details of which are given elsewhere.

Wednesday Evening

The meeting Wednesday evening was devoted to new and proposed A. I. E. E. Standards and was given under the auspices

of the Standards Committee, Mr. H. S. Osborne, Chairman. The meeting was called to order at 8:00 p. m. by Mr. L. W. W. Morrow, who introduced Mr. H. S. Osborne, who acted as chairman. Mr. Osborne gave a brief outline of the methods and work of the Standards Committee and then called for the presentation of *Standards for Industrial Control Apparatus*, by Mr. H. D. James, in whose absence the subject was presented by Mr. Burnham.

The next paper, *Standards for Electric Arc Welding Apparatus*, by F. M. Farmer, was presented by Mr. Bates in the author's absence.

Mr. A. W. Whitney, Chairman of the American Engineering Standards Committee, was next introduced and gave a most interesting address, the title of which was *The Place of Standardization in Modern Life*.

Standards for Synchronous Converters, by J. C. Parker, was next presented by Mr. L. B. Bennett, after which Mr. R. E. Argersinger presented the paper *Insulator Test Specification Standards*. This was followed by Mr. D. R. Dalzell who presented a report on *Standards for Transformers, Induction Regulators and Reactors*. Mr. Paxton made a brief report on *Standards for Direct-Current and Alternating-Current Fractional Horsepower Motors*, and Professor P. M. Lincoln spoke for the Working Committee on *Standards for Induction Motors*.

The subject was then thrown open for discussion, which was participated in by Messrs. E. P. Peck, C. W. Bates, E. D. Ewing, Arthur G. Pierce, R. Baker and B. G. Jamieson.

Musicale

Wednesday evening Professor Karapetoff gave one of his delightful piano recitations. He chose as his subject for the evening Schumann's "Carneval." He first played the individual themes which make up the composition, explaining each as he proceeded. Then, after the rendering of vocal numbers by Madam Louise Bernet, Professor Karapetoff played the entire Carneval as a unit.

Thursday Morning

Two sessions were held in parallel Thursday morning, one being devoted to transmission and the other to various protective devices.

Session A, under the auspices of the Transmission and Distribution Committee, Mr. F. G. Baum Chairman, was called to order at 10:00 o'clock by Mr. H. W. Eales. The following papers were presented in abstract by their authors; *Underground A-C Network Distribution*, by A. H. Kehoe; *General Light and Power Supply of Chicago*, by G. M. Armbrust and J. B. Jackson: *Study of Underground Distribution Systems*, by W. R. Bullard; *Equivalent Single-Phase Networks for Calculating Three-Phase Short-Circuit Currents*, by R. A. Shetzline; *Standardization in Construction and Operation*, by M. L. Sindeband. These papers were then discussed as a group by Messrs. E. R. Thomas, E. B. J. Stuart, F. C. Hanker, A. H. Sweetnam, R. A. Paine, E. P. Peck, H. M. Trueblood, H. W. Smith, H. A. Stanley, W. L. Abbott.

Session B, under the auspices of the Protective Devices Committee, Mr. H. R. Woodrow, Chairman, was called to order by Vice-President Schuchardt who called upon Vice-President Henderson and Mr. H. R. Woodrow to asist in direction of the meeting. The following group of papers was then presented in abstract by their authors; *Current-Limiting Reactor Characteristics*, by S. I. Oesterreicher; *Design, Installation and Operation of Current-Limiting Reactors*, H. O. Stephens and F. H. Kierstead; *Current-Limiting Reactors*, by W. M. Dann; *Theory of the Saturated-Core Regulator and Reactor*, by A. Boyajian; *Application of the Saturated-Core Regulator and Reactor*, by D. K. Blake. The papers were then discussed as a group by Messrs. O. E. Schurig, N. L. Pollard, O. E. Charlton, John E. Jackson, R. A. Hentz, W. B. Kirk, Joseph Slepian and V. Karapetoff.

Dinner Dance in Donjadah

A most enjoyable evening was spent Thursday at the dinner dance in Donjadah. In this fanciful city everyone was a member of one of three mystic orders, the Sphinx, the Pirates or the Arabs. The atmosphere of the occasion and the original method used for getting everybody acquainted were so effective that formality was soon laid aside and there resulted an evening of lively pleasure.

Friday Morning

The final day of the convention had parallel sessions scheduled for the morning, one session being devoted to electrophysics and lighting, and the other to electrical machinery.

Session A was called to order at 10:00 o'clock by Vice-President Schuchardt, who made some brief announcements and then turned the conduct of the meeting over to Vice-President H. T. Plumb. This session was under the auspices of the Electrophysics Committee, Mr. F. W. Peek, Jr., Chairman, and the Lighting and Illumination Committee, Mr. G. H. Stickney, Chairman. The four papers pertaining to electrophysics which were abstracted by their authors were as follows: *High-Voltage Cables*, by William A. Del Mar; *The Dielectric Field in an Electric Power Cable*, by R. W. Atkinson; *Direct Method of Calculating Capacitance of Conductors*, by H. B. Dwight; *Improved Method of Measuring Potential Gradient and Flux Density in Irregular Fields*, by J. F. H. Douglas and E. W. Kane. This group of papers was discussed by Messrs. D. W. Roper, D. M. Simons, W. F. Davidson, R. Paine, H. W. Atkinson, V. Karapetoff, Herman Halperin, E. R. Thomas, A. F. Randolph, C. F. Hanson, E. W. Kane, A. H. Kehoe.

Following this discussion Chairman Plumb called upon Mr. Preston S. Millar to present his paper on *Some Notes on Street Lighting*, which was then discussed by Messrs. L. A. S. Wood, F. C. Caldwell, G. H. Stickney and F. C. Vaughn.

Session B was under the auspices of the Electrical Machinery Committee, H. M. Hobart Chairman, and was called to order at 10:00 o'clock by Chairman H. W. Eales. The papers for this session were presented in abstract by their authors as follows: *Flashing Characteristics of Series and Compound Motors*, by R. E. Ferris; *The 35,000-kw. Frequency Converter for Hell Gate Station*, by O. E. Shirley; *The Inertaire Transformer*, by W. M. Dann and D. R. Kellogg; *A New Type of Single-Phase Motor*, by S. R. Bergman; and *Theory and Calculation of the Squirrel-Cage Repulsion Motor*, by H. R. West. These were discussed as a group by Messrs. F. C. Hanker, A. H. Maude, L. H. Hill, V. Karapetoff, Val A. Fynn, Edward Bretch, P. M. Lincoln, G. H. Garcelon, D. R. Dalzell and C. F. Scott.

Illuminating Engineering Society's Luncheon

A luncheon with the Chicago branch of the Illuminating Engineering Society was enjoyed on Friday. Preston S. Millar gave an adress on illumination at this luncheon.

Other Entertainment

Each morning before the sessions began some form of entertainment was furnished. On Tuesday at 9:00 a. m. there was a style show held in the spacious lounge room of the hotel. On Wednesday morning before the technical sessions a first-aid exhibition was staged demonstrating methods to use in case of accidents, both electrical and otherwise.

Thursday morning opened with a parade of bathing beauties on the beach of Lake Michigan and an exhibition of fancy diving and swimming races.

A demonstration of the broadcasting of a studio program was offered as the first thing on Friday morning by the members of the hotel's radio station, WEBH. Vocal and piano selections were rendered and a humorous demonstration was given of an astounding radio receiving set, the "Super-ultra-neutro-heterodyne."

Inspection Trips and Drives

Probably the most enjoyed trip of the meeting was the excursion Wednesday by boat on Lake Michigan to the recently completed Calumet Station of the Commonwealth Edison Com-

pany. A large party including many ladies took this very pleasant ride. A buffet lunch was served on board.

Another trip in which there was much interest was made on Tuesday to the new high-pressure Waukegan plant of the Public Service Company of Northern Illinois. The trip was made by motor busses through the beautiful North Shore drives and residential districts.

The ladies enjoyed an automobile ride on Tuesday through the beautiful northern section of the city and suburban districts, taking luncheon at the Glen View Golf Club.

Many other trips of inspection were made including visits to the Hawthorne Plant of the Western Electric Company, the Central Office of the Illinois Bell Telephone Company, the Ilg Manufacturing Company, automatic railway substations of the Chicago, North Shore and Milwaukee Railroad and of the Chicago, Aurora and Elgin Railroad, a wire plant of the American Brass Company, a pole-treating plant of the Naugle Pole and Tie Company, the Lakeside Station of the Milwaukee Electric Railway & Light Company, stations of the Commonwealth Edison Company, etc.

Golf and Tennis

Both golf and tennis tournaments were held and were enjoyed by a large number. The tenth annual competition for the Mershon Golf Cup, donated by Past-President Ralph Mershon, was won by R. O. Bentley with a net score of 65 (86 gross). The runner-up was A. H. Sweetnam with a net score of 73 (gross 92). This cup will become the property of any member who wins it twice. There are now nine other names on the cup, namely, A. M. Schoen, J. C. Mock, E. W. Allen, L. F. Deming, A. A. Brown, M. G. Kennedy, Howard Maxwell, P. H. Chase and G. L. Knight.

In event No. 1 the winner of the prize for the best net score was R. O. Bentley who received six golf balls.

In event No. 2 the winners of the tournament were, first, R. H. Kilner who received six golf balls; and second prize of four balls was divided between S. P. Grace and D. W. Ellyson.

In the tennis tournament played on the courts of the Edgewater Beach Hotel, the singles title was won by G. A. Sawin. This gives him one leg on the Mershon Tennis Cup. This cup must be won twice by the same man before he may have permanent possession of it. Mr. Sawin also received a fountain pen as first prize and Frank V. Smith, his opponent in the singles finals, received a gold pencil. Messrs. Sawin and Smith won the doubles match, each receiving a thermos bottle as a prize while their opponents in the finals, R. L. Shepherd and E. H. Hubert received gold pencils.

The personnel of the Convention Committee under whose auspices this most successful convention was held is as follows: R. F. Schuchardt, Chairman, J. E. Kearns, A. W. Berresford, L. A. Ferguson, M. M. Fowler, C. H. Jones, Ernest Lunn, H. A. Lynett, J. C. Martin, T. Milton, L. W. W. Morrow, S. A. Rhodes, D. W. Roper, C. C. Grandy, Geo. E. Wagner, Ellery B. Paine, D. C. Pyke, S. H. Mortensen, E. L. Bailey, H. W. Meyer.

Geographical District No. 2

The Executive Committee of Geographical District No. 2 met at the Penn-Harris Hotel, Harrisburg, Pa., on June 6th. Representatives of the Baltimore, Erie, Philadelphia, Pittsburgh and Washington, D. C. sections attended. Vice-President William F. James of Philadelphia presided as Chairman and R. B. Mateer, chairman of the Philadelphia Section, acted as Secretary.

After a brief résumé of the work accomplished in the District in 1922 and 1923, the delegates were invited to suggest subjects for discussion in regard to ways of benefiting the Section.

The suggested subjects were discussed under two general headings:

(a) Those of National interest—which would be referred to the Standing Committee of the Institute, and

(b) Procedure of material interest to the Sections—upon which subjects constructive action would be taken by the Executive Committees.

Under the first general heading (a) Student affiliations, Colaboration on papers, Section papers, Character and presentation of papers in the Journal, Mid-winter conventions, Advancement of members to higher grade and technical reports were considered, while, under the second classification (b) Uniform notice of meetings, Scope of papers presented before the Section, Recording of papers, Coordination of Section activities—by interchange of Chairmen and authorized representatives, Geographical conventions and conduct and character of Section meetings, were given due consideration by the Section delegates.

In closing the sessions of the Geographical Conference, the Chairman, Vice-President W. F. James, requested that each Section give due consideration to the subjects discussed at the meeting on June 6th and be prepared to give further thought not only to the subject matter of this session, but to such other problems as may arise, at a conference to be called early in September, 1924.

The Vice President also requested that each of the Sections in Geographical District No. 2 be represented at the Sections conference on Monday, June 23rd, at Chicago.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the Edgewater Beach Hotel, Chicago, on Thursday, June 26, 1924.

There were present: Past President Frank B. Jewett, New York; Vice-President R. F. Schuchardt, Chicago, H. T. Plumb, Salt Lake City, H. W. Eales, St. Louis, J. E. Macdonald, Los Angeles, S. E. M. Henderson, Toronto; Managers Harold B. Smith, Worcester, E. B. Craft, H. P. Charlesworth, New York, A. G. Pierce, William McConahey, Pittsburgh, Harlan A. Pratt, Hoboken, H. M. Hobart, Schenectady, Ernest Lunn, Chicago, G. L. Knight, Brooklyn, N. Y.; F. A. Norris, representing Secretary F. L. Hutchinson, New York. By invitation: President-elect Farley Osgood, Newark, N. J., and Vice-President-elect L. F. Morehouse, New York.

Vice-President R. F. Schuchardt presided.

The following memorial resolutions to the late T. Commerford Martin, Past President and Charter Member of the Institute, were adopted:

Whereas the membership of the American Institute of Electrical Engineers has learned with profound regret of the death on May 17, 1924, of Thomas Commerford Martin, Past President and Charter Member, be it

Resolved: That the Board of Directors in session at the Fortieth Annual Convention of the Institute place on record as a tribute to his memory, its sorrow and sense of personal loss in the passing of one of its most distinguished members, and its grateful appreciation of the loyal, unselfish, devoted service which he brought not only to the Institute itself, but to the whole field of applied electricity; and be it further

Resolved: That the Institute extend to the members of his family its deep and heartfelt sympathy in their bereavement, and that this resolution be spread on the records of the Institute and that copies be transmitted to members of his family.

A report was presented of a meeting of the Board of Examiners held June 16, 1924; and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners the following actions were taken upon pending applications: 84 Students were ordered enrolled; 301 applicants were elected to the grade of Associate; 12 applicants were elected to the grade of Member; 1 applicant was elected to the grade of Fellow; 17 applicants were transferred to the grade of Member; 3 applicants were transferred to the grade of Fellow.

The Secretary reported 1029 members delinquent in the payment of dues for the fiscal year ending April 30, 1924. The

Board directed that the usual efforts be continued to collect these dues, through the Secretary's office and by bringing the list to the attention of the Section officers concerned.

Approval by the Finance Committee of monthly bills amounting to $20,707.35 was ratified.

Upon the recommendation of the Standards Committee, the Board voted to accept the invitation of the American Engineering Standards Committee to be one of the sponsors for a Sectional Committee on Engineering Abbreviations and Symbols.

Invitations were accepted to be represented at the celebration of the 100th anniversary of Rensselaer Polytechnic Institute, at Troy, N. Y., October 3-4, 1924; and at the inauguration of Robert Ernest Vinson as President of Western Reserve University, and at the dedication of the new buildings of the School of Medicine of that university, at Cleveland, October 9, 1924.

Resolutions were adopted expressing appreciation of the effective services of the members of the Convention Committee, "in making and carrying out with gratifying success the arrangements for the comfort and entertainment of the members and guests of the Institute attending the 1924 Annual Convention;" and of the many courtesies extended by various local organizations to the members and guests in attendance at the convention.

Presiding Officer Schuchardt received a telegram from President Ryan which he read to the members assembled in convention. The following message from the Board was telegraphed to President Ryan:

"The Board of Directors of the A. I. E. E. send most hearty congratulations on the splendid success of your administration and express sincere regret for the indisposition which prevented your attendance at this convention, which has followed the best traditions of the Institute in combining most important engineering activities with social intercourse under most happy conditions. We wish also to express our appreciation and admiration for your splendidly worded message read to the meetings yesterday in which your great thoughts have been expressed in such admirably condensed form."

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

British Association, Toronto Meeting

A group of the leading scientists of the United States will take part in the 92nd Annual Meeting of the British Association for the Advancement of Science, to be held at Toronto, Aug. 6-13.

H. C. Sherman and W. N. Eddy of Columbia University will speak on Aug. 11 and there will be an address by W. D. Bancroft of Cornell on Aug. 12th.

E. E. Slosson of Washington, D. C. and W. Lash Miller of the University of Toronto will take part in a discussion on photochemistry at the conclusion of the meeting.

The objects of the British Association for the Advancement of Science are officially stated as follows:

"To give a stronger impulse and a more systematic direction to scientific enquiry; to promote the intercourse of those who cultivate science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of science and the removal of any disadvantages of a public kind which impede its progress."

A large number of the participants in this conference will come to the United States for the meeting of the American Chemical Society at Cornell University, Sept. 8-13.

Uniform Safety Standards

A series of national safety codes is now being prepared by various sponsors under the auspices of the American Engineering Standards Committee, through committees widely representative of all interests involved; and the following codes have been completed and approved by the American Engineering Standards Committee, namely:

Code of Lighting Factories, Mills and other Work Places,

National Safety Code for the Protection of the Heads and Eyes of Industrial Workers,

Safety Code for the Use, Care and Protection of Abrasive Wheels,

Safety Code for the Protection of Industrial Workers in Foundries,

Safety Code for Power Presses and Foot and Hand Presses,

Safety Code for the Construction, Care and Use of Ladders,

Safety Code for Mechanical Power Transmission Apparatus.

At a recent meeting of the American Engineering Council, attention was called to the need for uniform safety standards throughout the United States, and the following resolutions relating to the above-mentioned codes were adopted:

RESOLVED: That the American Engineering Council recommends to administrative officers, employers and all others concerned that these codes be given wide application and be used in preference to other standards which may be developed locally or by bodies not so fully representative of the interests concerned, and

RESOLVED: That the Executive Officers of the American Engineering Council are hereby authorized to use their efforts in bringing these codes to the attention of those concerned with them in industry and administrative officials concerned with the enforcement of safety standards.

Copies of any of these codes may be purchased from the American Engineering Standards Committee, 29 West 39th Street, New York City.

Third National Exposition of Power and Mechanical Engineering

Notice has just been received that the Third National Exposition of Power and Mechanical Engineering will take place in Grand Central Palace, New York, N. Y., December 1-6. Space has been assigned to more than 260 exhibitors and all indications point to a large and enthusiastic attendance.

While the Exposition is in progress, meetings of the American Society of Mechanical Engineers, and the American Society of Refrigerating Engineers will be held in New York City, so the members will be able to attend the meetings and also see the exhibits. The management of the Exhibition is assited by an Advisory Committee of designing and operating engineers.

AMERICAN ENGINEERING COUNCIL

COAL STORAGE

The Storage of Coal Committee of the A. E. C. has recently issued a summary of a report which is the result of more than a year's survey of the national coal situation. Sixty-seven subcommittees, representing every important industry, as well as scientists and government officials, composed the personnel of the investigating organization.

The seasonal storage of coal as the chief means of relief is urged in this report, which states that such action will eliminate the danger of coal famine, stabilize industry, reduce prices and relieve congestion on the railroads during the fall and winter months. Not only would this practise help to make production more uniform, but it would benefit the consumers by reducing the mining costs and hence remove the evils of intermittent operation and consequent fluctuation in prices. The cost of storing coal is a very small item, especially when compared to the expense incurred on account of shutdowns and other results of coal shortage. The consumer is the one to start these reforms.

Benjamin G. Lamme

BENJAMIN G. LAMME, electrical inventor and engineer of world wide reputation, died on July 8th at East Liberty, Pa., after a lingering illness.

Mr. Lamme was born in 1864 in Clark County, near Springfield, Ohio and graduated from the Ohio State University in 1888, with the degree of mechanical engineer. While a student, he showed a remarkable ability in mathematics, and later when he was preparing specifications for his electrical inventions, he often made his calculations without pencil and paper. He also had the unusual faculty of being able to explain clearly and concisely his various conclusions in words that could be understood by the average engineer, without resource to intricate mathematical expressions. Mr. Lamme was a writer of note on electrical engineering subjects and a paper on the Induction Motor, published many years ago, has been included in the text books of the Naval Academy at Annapolis.

He entered the Testing Department of the Westinghouse Electric and Mfg. Co. in 1889 and worked under the late Albert Schmid and the late George Westinghouse who became much interested in him. While working to check up saturation curves on the alternating-current machines which were then in use, Mr. Lamme started the calculation of electrical machinery in the Westinghouse Co. In this same year Mr. Schmid requested him to make a study of the existing railway systems, with a view to "calculating" a suitable railway motor. In January, 1890 the first Westinghouse double-reduction motor was built, produced entirely from calculations.

Mr. Lamme was a most prolific inventor, having more than 150 patents. Chief among these are the "umbrella" generators which were first used in utilizing the power of Niagara Falls, the synchronous converter for converting alternating into direct current, the series commutator-type motor, which is now used on street and other electric transit systems.

Mr. Lamme at the time of his death was chief engineer of the Westinghouse Electric and Mfg. Co., and chairman of the board of editors of the "*Electric Journal*," its engineering magazine. He was one of two members of the Institute who were appointed on the Naval Consulting Board during the war, and was chairman of the Inventions' Committee of that Board.

In 1919, at the Annual Meeting of the Institute he was awarded the Edison Medal "for invention and development of electrical machinery," and in 1923 he received the Joseph Sullivant medal from the Board of Trustees of the Ohio State University.

Mr. Lamme became an Associate of the Institute in 1903 and the same year was transferred to the grade of Member. He was urged to accept the nomination of Vice-President of the Institute, but declined on account of the pressure of business. He was much interested in students who came with the Westinghouse Co. and maintained a design school for these men, giving them the benefit of his personal knowledge and experience.

On the announcement of Mr. Lamme's death at the World Power Conference, in session on July 11th, the following resolution was passed by the Conference, standing in silence for a brief period:

WHEREAS the first World Power Conference learns with deep regret of the death of Mr. Benjamin G. Lamme, Chief Engineer of the Westinghouse Electric & Manufacturing Co., Delegate to the Conference and the author of a Power Conference Paper describing "American Power Station Equipment" And whereas Mr. Lamme is well-known for his inventions of electric power apparatus and his articles on technical subjects And whereas through his death one of the great electrical designers has passed away, a man of most unassuming and charming personality, the delegates of the World Power Conference join in sending sincere sympathy to his relatives in their great loss.

With the death of Benjamin G. Lamme, the electrical industry has lost one of its greatest men. His name ranked with that of the late Charles P. Steinmetz, and the results of his engineering achievements will be a lasting tribute to his memory.

NATIONAL RESEARCH COUNCIL

MINIMUM SPECIFICATIONS FOR HIGHWAY ENGINEERING POSITIONS

The National Research Council, through its Advisory Board on Highway Research, has recently issued as Bulletin 45, a unique report on "Minimum Specifications for Highway Engineering Positions." The report was prepared by a special committee appointed by the American Association of Engineers. This committee, with A. B. McDaniel as Chairman, has had the official cooperation of the United States Bureau of Public Roads and of several State Highway Commissions and Municipal Bureaus.

The report lists the essential qualifications for the filling of 17 typical highway engineering positions. It also presents a series of 117 actual problems which have arisen in the everyday work involved in carrying out the duties of the various positions. The solutions used are given in some instances and are available for all the problems.

This report is intended to be of practical service to those concerned with the proper selection, assignment, promotion, transfer or training of highway engineers.

This book may be obtained from the Washington Office of the National Research Council for $1.00.

APPOINTMENT OF CHARLES P. UPHAM

Charles M. Upham, State Highway Engineer of North Carolina, has been recently appointed Director of the Advisory Board on Highway Research of the National Research Council, Washington, D. C., to succeed W. K. Hatt who resigned in order to resume his work at Purdue University.

The present Board intends to continue the excellent plans already effected and to extend its activities so that the results of highway research may be practically applied by the States and Counties carrying on programs of highway construction and maintenance and by others interested in highways. The organization has been extended so that each State Highway Department may have a representative on the Board who will serve as a point of contact between it and the State. It is also planned to have similar representation from universities engaged in highway research.

Mr. Upham, the new Director, has had extensive experience in highway work. He received his early training with the Massachusetts Highway Department and later became Chief Engineer of the Coleman du Pont Road. Following this, he was for four years Chief Engineer of the Delaware State Highway Department when he was called to take charge of the extensive highway construction program in North Carolina. Mr. Upham holds a B. S. degree from Tufts College and an honorary C. E. degree from the University of North Carolina. He is an Associate Member of the American Society of Civil Engineers and holds active membership in many other technical societies. For the past two years he has been Business Director of the American Road Builders' Association and has been re-elected several times to his present position as Secretary of the American Association of State Highway Officials.

It is expected that Mr. Upham's wide acquaintance and broad experience in the highway field will make his connection as Director of the Advisory Board on Highway Research especially valuable to those agencies which can utilize the information being made available by this organization.

Philadelphia Section Wins Athletic Meet from Mechanicals

Following the custom of former years, the members of the Philadelphia Sections of the American Institute of Electrical

Engineers and the American Society of Mechanical Engineers gathered on June 18th, 1924, for the 1924 Field Day and the principal vocation of all present seemed to be participation in athletic events, golf, tennis and baseball. The Electricals won the baseball game by a score of 11 to 7—retrieving their defeat of the preceding year. They also won at tennis while the Mechanicals won the golf match.

The prize for the meet, a silver cup presented by Rose B. Mateer, Chairman of the Philadelphia Section, A. I. E. E., was awarded to the Electricals at a dinner following the meet. This cup will become the permanent possession of the group which wins it twice.

Standards for Industrial Control Apparatus

FIRST REVISED SECTION OF THE A. I. E. E. RULES NOW AVAILABLE

On May 16, 1924, the Board of Directors adopted "Standards for Industrial Control Apparatus" as part of the A. I. E. E. Standards. This revised section of the rules, now available in pamphlet form, is the first of a series of sections, each dealing with a specific subject to be issued from time to time, as the work of the entire revision of the present Rules now in process is completed. It is believed that this division of the rules will simplify the work of keeping the Standards Rules in conformity with the latest developments and enable those interested in a particular field to obtain by itself material covering that field.

"Standards for Industrial Control Apparatus" deals with service conditions, definitions, rating, heating, limitations other than heating, and dielectric strength of industrial control apparatus and similar control used for industrial heating, rheostats and auto transformers. Marine auxiliaries and propulsion control apparatus, mine locomotive control apparatus and railway control apparatus are not included.

This pamphlet can be obtained at a cost of 25c. by applying to Institute headquarters, or it will be furnished until further notice without additional charge as a supplement with each copy of the 1922 Standards; cost per copy $2, (A. I. E. E. members, $1.50).

CRITICISMS AND SUGGESTIONS WELCOME

In the work of the revision of the Standards, every effort is made to make the committees performing the work representative of all interests involved, so that the final report may record the best American practise and experience. In addition, with a view to obtaining the opinions, criticisms and suggestions of as many interested persons as possible, it has been deemed advisable to issue in printed form previous to final action by the Standards Committee, such "Reports of Working Committees" as become available from time to time. Five such pamphlets are now available and may be obtained, without charge, by those interested by applying to Institute headquarters. The Sections covered are as follows:

No. 8—Report on Standards for Synchronous Converters.
No. 10—Report on Standards for Direct and Alternating-Current Fractional Horsepower Motors.
No. 13—Report on Standards for Transformers, Induction Regulators and Reactors.
No. 38—Proposed Standards for Electric Arc Welding Apparatus.
No. 41—Report on Insulator Test Specification Standards.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES (June 1-30, 1924)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

ALIGNMENT CHARTS FOR ENGINEERS AND STUDENTS.

By W. J. Kearton and George Wood. Lond., Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1924. 220 pp., diagrs., charts, 9 x 6 in., cloth. $6,50.

A textbook for students of nomography and a reference book for engineers. The authors first discuss at length the principles that underly the construction and operation of nomograms, then give directions for the practical construction of them. A series of diagrams showing the arrangement of lines for equations with from three to six variables is given. Nearly one-half of the book is occupied by a collection of thirty-five charts which represent some of the more important formulas used in various branches of engineering. These include charts for the strength of cylinders and shafting, of circular flat plates, of gearing and of springs; for the flow of water in pipes and through orifices, for earth pressures on walls, etc.

ALTERNATING CURRENT BRIDGE METHODS FOR THE MEASUREMENT OF INDUCTANCE, CAPACITANCE AND EFFECTIVE RESISTANCE AT LOW AND TELEPHONIC FREQUENCIES.

By B. Hague. Lond., & N. Y., Isaac Pitman & Sons,1923. 302 pp., diagrs., 9 x 6 in., cloth. $4.50.

The importance of these methods of measurement in telegraphy, telephony and radio-technology has led to the preparation of this work. Chapter one discusses the quantities dealt with and electrostatic phenomena. Chapter two develops the theory of alternating currents from the point of view of the

symbolic method. In chapter three, the apparatus required is considered at length. The various bridge networks are classified in chapter four, and the theory, uses and laboratory procedure are given for each. Chapter five deals with the choice of the method for a given measurement. The book pays particular attention to the experimental side of the subject, but at the same time attempts to provide a logical treatment of the theory underlying the use of these networks.

AUTOMATIC TELEPHONE SYSTEMS, vol. 3.

By William Aitken. Lond., Ernest Benn, 1924. 339 pp., illus., diagrs., 11 x 9 in., cloth. 55s.

This, the final volume of this comprehensive work, treats of automatic systems for large cities, combination manual and automatic systems, metering telephone calls, miscellaneous system switching devices and circuits and wiring schemes. The author has tried to include all the important systems that are in use or nearly ready to be brought into use but has not attempted to describe all that have been patented. Particular attention is given to the Stronger, Western Electric and Ericsson systems.

AUTOMATIC TELEPHONES.

By F. A. Ellson. Lond., & N. Y., Isaac Pitman & Sons, 1924. (Pitman's Technical Primers). 215X pp., illus., diagrs., 7 x 4 in., cloth. $1.50.

Will be useful to those who wish a concise, elementary text. The system of the Automatic Telephone Manufacturing Company is described in full, and the systems of Siemens, the Western Electric Company and the Relay Automatic Telephone Company are explained more briefly. A bibliography is included.

DEVELOPMENTS IN POWER STATION DESIGN.

By Edwin Austin. N. Y., D. Van Nostrand Co., 1924. 271 pp., illus., diagrs., 11 x 8 in., cloth. $9.00.

Present interest in more efficient utilization of national power resources is the reason for the publication of this book, which is based on a series of articles that appeared in "The Engineer" during 1921 and 1922. The author describes modern power-plant practise in Great Britain and elsewhere, paying particular attention to the devices and methods that promise great efficiency. The account is descriptive, rather than technical, and is intended primarily for those connected with large public electric plants. It is based on personal visits to power plants and on information obtained from specialists.

DYNAMICS.

By Horace Lamb. 2d edition. Cambridge, England, University Press, 1923. 351 pp., 9 x 6 in., cloth. 12s 6d. (Gift of Macmillan Co., N. Y.)

A textbook forming a sequel to the author's "Statics," the two giving a thorough introduction to mechanics. The present edition has been revised, some pages rewritten and new exercises added.

ELECTRICAL MEASURING INSTRUMENTS AND SUPPLY METERS.

By D. J. Bolton. N. Y., E. P. Dutton & Co., 1924. (Directly-useful technical series). 328 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

This book is intended to cover all the measuring instruments and meters generally met with in engineering practise, including both indicating and supply instruments, and covering the measurement of magnetic properties and of temperatures as well as purely electrical phenomena. It is written for the general engineer rather than the research worker or the manufacturer, and aims to give the information needed by the former class in a brief, inexpensive form.

ELEMENTS OF ELECTRICAL DESIGN.

By Alfred Still. N. Y., McGraw-Hill Book Co., 1924. 535 pp., diagrs., tables, 9 x 6 in., cloth. $5.00.

This book is intended for students of electrical engineering. Its aim is not to train designers but to use the practical problems that confront him as a means for aiding all students to understand the fundamental principles of electricity by showing how these principles are applied. The earlier chapters discuss the electric, magnetic and electrostatic circuits. In later chapters, various machines and apparatus are considered and a number of problems in design are solved numerically.

ELEMENTS OF STEAM AND GAS POWER ENGINEERING.

By Audrey A. Potter and James P. Calderwood. 2d edition. N. Y., McGraw-Hill Book Co., 1924. 339 pp., illus., diagrs., 8 x 6 in., cloth. $2.75.

A brief textbook for students in engineering schools. Intended to familiarize them with power-plant equipment before they study thermodynamics and de ign. Should also interest those who are responsible for the operation of power-plants, as it presents the principles that underly the construction and operation of steam and gas power equipment clearly and concretely. Chapters on the locomotive and automobile are included.

HAND-BOOK OF FIRE PROTECTION.

By Everett U. Crosby, Henry A. Fiske and H. Walter Forster. 7th edition. N. Y., D. Van Nostrand Co., 1924. 899 pp., illus., diagrs., 7 x 5 in., fabrikoid. $4.00.

This handbook affords to students of the subject a concise, reliable account of approved practise. The general causes of fire and the special hazards of various industries are explained, the spread of fire and the lessening of danger by structural means are discussed, special information being given on proper construction for special purposes. Another section treats in detail of public and private equipment for extinguishing fires. Many useful tables and minor articles are included, making the volume a convenient reference work.

LIGHT AND WORK.

By M. Luckiesh. N. Y., D. Van Nostrand Co., 1924. 296 pp., diagrs., plates, tables, 9 x 6 in., cloth. $4.00.

The aim of this book is to analyze natural lighting, to point out its important fundamentals, to suggest improvements, to reveal the relations between lighting and vision, and to show the economic results from adequate proper lighting, measured in increased safety, efficiency and happiness. These discussions summarize the results of many researches in the laboratory and in practise, which are of interest to lighting specialists, engineers and employers.

MANUAL OF ENGINEERING DRAWING.

By Thomas E. French. 3rd edition, rev. & enl. N. Y., McGraw-Hill Book Co., 1924. 409 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

This is a textbook with a collection of tested problems, grouped and graded, and following current engineering practise. This new edition has been thoroughly revised and new problems and text added. The new matter includes chapters on Working Drawings, Perspective and Charts.

MECHANICAL REFRIGERATION.

By Hal Williams. New & enlarged edition. Lond. & N. Y., Isaac Pitman & Sons, 1924. 501 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

Written from the viewpoint of the owner, manager and student, rather than from a purely technical one. Discusses the general principles involved, the historical development, the properties of the usual refrigerants, the types of machines in use, the refrigerating plant and the auxiliary plant. Chapters are devoted to insulation and brine. The application of refrigeration for making ice, for cold storage and for other purposes is described, and there is a special chapter on the cold storage and packing of meat.

STORAGE BATTERIES.

By George Wood Vinal. N. Y., John Wiley & Sons, 1924. 402 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.50.

Although there is considerable literature on storage batteries, most of it is scattered and a book that summarizes the physical and chemical facts about them and describes their applications, is very desirable. The present book presents the scientific principles that underly the operation of storage batteries and gives a detailed description of the essential processes of manufacture, paying especial attention to the electrolyte. It then discusses operation, including charging, discharging, regulation, operating costs and troubles. There are also chapters on testing and on various applications and the appropriate batteries for it.

SPECTROSCOPY, vol. 1.

By E. C. C. Baly. 3d edition. Lond., & N. Y., Longmans, Green & Co., 1924. (Text-books of physical chemistry). 298 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

Professor Baly presents spectroscopy from the practical side in this work, his book being intended to assist those undertaking work in this field, by giving them as full details as possible of the methods of working with the various types of instruments.

The advance in the science of spectroscopy since the previous edition of this book appeared has made it necessary to enlarge this treatise to two volumes. The present one includes the first half of the original volume and deals with the standard methods of work in the infra-red, visible and ultra-violet regions of the spectrum.

WELDING ENCYCLOPEDIA. 4th edition.

By L. B. Mackenzie and H. S. Card. Chicago, Welding Engineer Publishing Co., 1924. 435 pp., illus., 9 x 6 in., fabrikoid. $5.00.

This new edition appears less than a year after the third, owing to the latter having become exhausted. Additions have been made to the rules and regulations affecting the industry and of methods for procedure in a number of important jobs of railroad welding.

The book is a convenient digest of present developments in welding, accompanied by working instructions for the operations commonly found in the industries, the official rules and regulations covering welding, and a training course for welders. The book covers arc and resistance electric welding, oxy-acetylene and thermit welding.

Popular Research Narratives

A most interesting little book containing tales of discovery, invention and research has recently been published under the name of "Popular Research Narratives." It is composed of 50 stories, collected by the Engineering Foundation. These have been written by the discoverers and inventors themselves and are told in a way that can be easily understood. Teachers, lecturers, students and the general public will all find this of interest. Copies of this book may be obtained from the Engineering Foundation at 50 cents each.

PERSONAL MENTION

ARNALD C. BURKE has announced the formation of The Burke Electric Co., 357 College Street, Toronto.

S. H. EXCELL is now inspector of steam boilers and machinery of the Provincial Government, New Westminister, B. C.

W. E. OSBORNE has severed his connections with the Western Electric Co., Ltd., London, and is now at 312 West 4th Street, Erie, Pa.

ROY H. HART, formerly Inspection Engineer of Gray & Davis, Inc., is now connected with the Western Electric Co., Inc., New York City.

G. N. LEMMON, is now president of the Southern States Equipment Co., 1921 Powell Ave., Birmingham, Ala. Formerly, his address was Electro Service Co., Marietta, Ga.

DUGALD C. JACKSON and EDWARD L. MORELAND, of the firm of Jackson & Moreland, have moved their offices to the Park Square Bldg., 31 St. James Avenue, Boston, Mass.

C. A. MULLEN is now with the Pennsylvania Power & Light Company, 117 East Broad St., Hazleton, Pa. He was formerly with the Ohio Service Company, Coshocton, Ohio.

H. B. CLARK, formerly Electrical Engineer with the N. Y. N. H. & H. Rwy., has taken the position of Electrical Designing Engineer with the Solvay Process Co., Solvay, N. Y.

K. W. MILLER of 1332 N. Water St., Decatur, Ill., is planning a three months' trip to Europe, visiting various points of interest in England, France, Germany, Switzerland and Italy.

R. H. RICHARDS, electrical and mechanical engineer of the Compania Chilena de Electricidad, Ltd., Santiago, Chile, is now touring the United States on a six months' vacation.

ROSCOE D. BEAN has been appointed Chief Engineer of the Brown Instrument Company, Philadelphia, Pa., having severed his connections with the Roller-Smith Co., Bethlehem, Pa.

F. F. EVENSON has accepted the position of Production Engineer with the Benson Lumber Company, San Diego, Cal. Mr. Evenson had been connected with the Bureau of Power and Light, Los Angeles, Cal.

L. M. DRAKE of Daytona, Florida has been elected Vice-chairman of the Florida Section of the American Chemical Society. He was also recently granted Fellowship in the American Institute of Chemists.

JOHN K. STAFFORD has resigned his position as instructor in mathematics at Rennselaer Polytechnic Institute and has accepted a position with the Lightning Arrester Dept. of the General Electric Co., Pittsfield, Mass.

MASAJI YOKOYAMA has become president of the Masashi Engineering Company, 60 Ogawamachi, Tokyo, Japan. He is also Director of the Board of the Furukawa Electrical Industrial Co.,.Yaesucho, Kojimachi, Tokyo, Japan.

REID L. RAYNOR, who for the past two years has been Graduate Assistant in the Electrical Engineering Dept. of the Michigan Agricultural College, has completed his graduate work and is now located with the Michigan Bell Telephone Co. at Grand Rapids, Mich.

GEORGE C. OXER has been appointed manager of the Eastern Sales District of the Jeffrey-DeWitt Insulator Company and the Champion Switch Company, with headquarters in New York. Colonel Oxer was formerly with the J. G. White Engineering Corporation.

LYLE WM. WICKERSHEIM has returned to the Bell Telephone organization after being manager of the Wickersheim Implement Co., Fullerton, Cal. He is now in the toll equipment department of the Southern California Telephone Co., South Olive St., Los Angeles, Cal.

EZRA H. DAY left the employ of the Standard Underground Cable Co. and is now associated with the Engineering Equipment Company as sales engineer. This company is an agent for the Condit Electrical Mfg. Co., Boston, Mass. and for the Packard Electric Co., Warren, Ohio.

JOHN S. KILNER resigned from the Ingersoll-Rand Company, where he has been employed for the past eight years on sales engineering, and has become a partner in the sales agency firm of Kilner-Mills Company, which succeeds the Power Equipment Company as representatives in the Detroit and Toledo district.

DR. L. H. BAEKELAND of Yonkers, New York, President of the American Chemical Society and Honorary Professor of Chemical Engineering in Columbia University, has just been highly honored by King Albert of Belgium, who made him Commander of the Order of Leopold. Dr. Baekeland has already received such distinctions as Officer of the Legion of Honor of France and Officer of the Crown of Belgium.

WALTER C. ALLEN has resigned as Executive Secretary to the Public Utilities Commission, Washington, D. C., and accepted a position with the Welsbach Street Lighting Company. Mr. Allen will have charge of the newly-created electric lighting department, as up to this time the Welsbach Company has specialized in gas street lighting, and his many years of experience in this line will be a great asset in his new work.

Obituary

SAMUEL HARVEY MCLEARY, Major, Coast Artillery Corps, U. S. Army, was robbed and murdered on July 2 near Cheraw, S. C. Major McLeary had been motoring from Norfolk, Va. alone on his way to Fort Moultrie, S. C. when two men hailed him and asked to be given a lift. Major McLeary cheerfully complied and after driving a few miles one of the men drew a pistol, ordered him out of the car and shot him. The body was then stripped of valuables and hidden and the men drove off. Both of them have been found and have confessed.

Major McLeary became an Associate of the Institute in 1903. He has been stationed in various parts of the United States and the Philippines and served in France from 1918-1919.

Howard Waring Thomas, inspector of Electrical material, 11th Naval Dist., Public Works Dept., San Diego, Cal., died on June 12, 1924 at the Naval Hospital in that city. Mr. Thomas had formerly been stationed at the Bureau of Steam Engineering, Navy Dept., Washington, D. C. and also at Portsmouth, N. H. Later he was transferred to the Pacific Coast. Mr. Thomas became an Associate of the Institute in 1919 and took an active interest in its affairs.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the members of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—Mamerdo Bauer C., Braden Copper Co., Rancagua, Chile, S. A.
2.—H. E. Bradley, 1 Pine Crest Drive, Hastings-on-Hudson, N. Y.
3.—John D. Brown, Celite Products Co., Box 639, Lompoc, Cal.
4.—H. H. Douglas, c/o So. Cal. Edison Co., Porterville, Calif.
5.—W. T. Hutton, 6753 South Bishop St., Chicago, Ill.
6.—Erle M. Jones, 370 Pape Ave., Toronto, Ont., Can.
7.—Albert H. Lindley, 2616 Kate Ave., Baltimore, Md.
8.—Fred. H. Nash, Box 366, Cushing, Okla.
9.—B. A. Ross, Phoenix Utility Co., Hazleton, Pa.
10.—Thos. W. Rule, 500 Central National Bank Bldg., Topeka, Kans.
11.—Kenneth H. Sloan, 11 Spruce Road, Inwood, L. I., N. Y.
12.—R. L. A. Strathy, 369 Clarke Ave., Apt. 5, Westmount, Que., Can.
13.—John B. Suttor, Jr., Mazda House, Wentworth Ave., Sydney, N. S. W., Australia.
14.—Hideo Yamada, 2 Nagasumi-Cho, Asakusaku, Tokyo, Japan.
15.—Adolph L. Ziegler, Westinghouse E. & M. Co., 160-7th St., Brooklyn, N. Y.

Past Section and Branch Meetings

SECTION MEETINGS

Atlanta

W. R. Collier spoke of the history of the A. I. E. E. in the South, calling attention to the part played by the Atlanta Section. The following officers were elected: Chairman, W. R. Collier; Vice-Chairman, F. B. Davenport; Secretary-Treasurer, H. N. Pye; Directors, Geo. J. Yundt and W. W. Bellew. June 19.

Boston

Entertainment by the Edison Company men, including piano duets, songs and a playlet, entitled "The Radioliar." A dinner preceded the entertainment. The following officers were elected: Chairman, F. S. Dellenbaugh; Vice-Chairman, W. R. McCann; Secretary-Treasurer, W. H. Colburn; Executive Committee, Hartley Rowe, R. D. Booth, H. B. Richmond and F. D. Hallock. May 19. Attendance 185.

Cincinnati

The Proposed Industrial Survey for Cincinnati, by Dean Herman Schneider. The following officers were elected: Chairman, Oscar Shepard; Secretary-Treasurer, Ernest Fields; Executive Committee, H. C. Blackwell, F. R. Healey, O. H. Hutchings, T. C. Reed, H. M. Walmsley. June 12. Attendance 53.

Milwaukee

Magnetic Clutches, by E. T. Foote, Cutler-Hammer Manufacturing Company. The following officers were elected: Chairman, C. T. Evans; Secretary, F. K. Brainard. June 11. Attendance 85.

Minnesota

Dinner Dance. May 6. Attendance 90.

Long Distance Telephony, by A. F. Rose, American Telephone & Telegraph Company. The speaker also gave a description of the public address system and a discussion of radio broadcasting problems. May 26. Attendance 92.

The following officers were elected: Chairman, E. H. Scofield; Secretary, Allen Dewars. June 17. Attendance 21.

Portland

Joint meeting with N. E. L. A. An excursion was made to Hillsboro, Oregon, where a picnic supper was served, followed by musical numbers and dancing. En route to Hillsboro, short side trips were made to inspect the commercial radio transmitting station of the Federal Telegraph Company and one of the automatic 1500-volt railway substations of the Oregon Electric Railway Co. June 16. Attendance 150.

San Francisco

Manufacture of Porcelain Insulators, by R. P. Jackson, Westinghouse Electric & Manufacturing Company. After the address, members and visitors were conducted through the high-voltage insulator factory of the above company. May 23. Attendance 95.

Spokane

The following officers were elected: Chairman, James S. McNair; Vice-Chairman, G. S. Covey; Secretary-Treasurer, Joesph Wimmer; Executive Committee, John B. Fisken, H. L. Melvin and D. H. Henderson. Plans for the coming year were discussed. May 23. Attendance 21.

Toledo

Telephone Traffic and Engineering Work of the Ohio State Telephone Company, by Mr. Foster and Mr. Briggs. Refreshments were served. June 6. Attendance 20.

Urbana

The following officers were elected: Chairman, Chas. T. Knipp; Secretary, Chas. A. Keener. June 2. Attendance 17.

Utah

Joint meeting with Utah Society of Engineers. The following officers were elected: Chairman, H. W. Clark; Secretary-Treasurer, John Salberg; Executive Committee: C. R. Higson, Lester B. Johnson, Wm. M. Scott, Leo Brandenberger and Paul P. Ashworth. May 31. Attendance 80.

BRANCH MEETINGS

Denver University

Novel A.-C. Voltmeters, by A. H. Patton, student.

Automatic Substations, by K. B. Schuman, student. May 23. Attendance 11.

University of Texas

A very entertaining farce "The Lie Detector" on an alleged electrical development was presented by D. C. Hoffman. W. J. Kirk, Austin Municipal Light Plant, told of his experiences in power plant operation. April 22. Attendance 15.

Present Electrical Developments throughout the World, by R. F. Calhoun, student. O. G. Wolf, student, gave some interesting data in regard to the 65,000-kv-a. generator of the Niagara Falls Power Company. J. M. Bryant outlined the work of the convention of Southern Engineers in New Orleans in April. May 5. Attendance 15.

Power Station Economics, by E. T. Keck, Texas Power and Light Company. The speaker outlined some of the plans now being developed for a "superpower" and interconnection in Texas.

The Oil and Gas Situation in Texas, by Judge H. E. Bell, Texas Railway Commission. The methods and regulations now in use to conserve the oil and gas resources of Texas were outlined. May 19. Attendance 30.

University of Washington

Columbia River Project, by Willis T. Batchellor, Consulting Engineer. The following officers were elected: Chairman, John Weir; Secretary, James W. Lewis. June 3. Atetndance 18.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

SALES ENGINEERS, for all sections of the U. S. and Canada, to sell patented electrical device to industrial plants, exclusive territory, straight commission basis. R-4146.

SALESMAN, to represent machines devoted to industrial motors and power house equipment, for company manufacturing mica undercutting machines. Location, Ohio. The Hullhorst Micro-Tool Co. R-4221.

METER ENGINEER, college graduate preferred with at least four years' experience in connection with meter department routine. Must be qualified to supervise tests, inspections and wiring checks of watt hour meters and maximum demand equipment on high tension installations. Alternating current theory essential. State salary desired and when available. Send photograph and copy of references. Location, New York City. R-4134.

ASSISTANT TO ENGINEER, in charge of lamp life test. Engineer student or graduate is needed who has had good mathematical experience. Must be of good appearance and must be in good physical condition, able to pass a satisfactory physical examination and in addition must be prepared to travel if necessary. R-4278.

MEN AVAILABLE

ELECTRICAL AND MECHANICAL ENGINEER, age 37, graduate of a leading technical university. Twelve years' broad experience in design and construction of steam and water power plants, three years' design and sales of water power machinery. Desires a responsible connection with a power company, consulting engineer or water wheel manufacturer. At present employed. B-4447.

ELECTRICAL ENGINEER, technical graduate, age 34, married. Eight years on engineering, design and construction of power plants, substations and industrial installations with largest engineering, industrial and public utility corporations. Can get results. Available thirty days after agreement. B-3573.

ELECTRICAL ENGINEER, 34. G. E. testing, six years construcion, operation, research, testing, maintenance, meters, assistant chief engineer and superintendent technical department 110,000 volt hydro-electric power system, four years consulting and commercial engineering. Speaks Spanish, French, German, etc., will change present position. Best references. B-8354.

ENGINEER with unusually broad industrial experience wishes foot-hold in progressive manufacturing organization. Practical machinist, wood-worker, technical education. Experienced as executive and as investigator. B-4017.

TECHNICAL GRADUATE IN E. E., age 37. Sixteen years in design and construction of power plants, substations and transmission lines. Available on reasonably short notice. B-8277.

OPERATING ENGINEER, technical education, eight years' experience in system operation and dispatching, maintenance, construction, inspection, operation and testing of all classes of substations from 132 Kv. outdoor down to Edison three wire city stations. B-8298.

ELECTRICAL ENGINEER, desires position as superintendent or manager of electrical utility property in city of 5000 to 10,000 population. Experience covers four years as superintendent of several southern cities, three years as assistant distribution engineer in one of the growing cities of Texas caused by oil booms. Preference as to location north central states or foreign. B-8319.

GRADUATE ELECTRICAL ENGINEER, 24 years of age. Nine months' experience shell manufacturing, two months' experience small tests, sixteen months' experience switchboard design and responsible charge of drafting, wiring and factory assembly. Now employed. Desires change of location with future for executive work and application of originality. B-6918.

RECENT GRADUATE of University of Michigan, B. S. in E. E., Student Member A. I. E. E., age 22. Has had some practical experience. Desires position in electrical engineering with opportunity to advance. Location in Detroit or New York preferred. B-8310.

ELECTRICAL AND MECHANICAL ENGINEER of wide experience in the installation, operation and rehabilitation of industrial plants seeks connection with industrial enterprise with a view to managing electrical and mechanical department, as chief engineer or master mechanic. Would consider financial interest to the extent of $10,000 to $25,000 with a company that can stand close investigation. B-8327.

WRITER, EDITOR OR INVESTIGATOR, graduate Electrical Engineer, wants position where ability to write technical matter in clear, concise, readable English will be of value. Not merely a copy writer, but an experienced engineer. Special reports made on any engineering subject. Has done similar work for largest automobile corporations. Age 35. A-165.

ELECTRICAL ENGINEERING GRADUATE, 1923, eight months' experience wiring department of central station, wishes work along electrical lines. Knows Spanish well. B-8318.

RECENT GRADUATE IN ELECTRICAL ENGINEERING desires practical work, with opportunity for advancement, to acquaint him with manufacturing methods and electrical engineering practise. Would prefer to work into electrical research or design. No engineering experience but willing to work. Good references. Available July 15th. B-8317.

ENGINEERING EXECUTIVE — technical graduate, fifteen years' experience, ten years electric utility manager, can make a property pay and build sound public policy, rate making, power sales. Desires position with electric utility or sales work with engineering concern. Age 37, married, available two weeks. B-6090.

GRADUATE ELECTRICAL ENGINEER, age 23, single, with four years' experience on repair and installation of electrical machinery, also considerable troubleshooting and inspection work. Would like position as a maintenance engineer. Location immaterial, will consider foreign employment. B-8349.

ELECTRICAL ENGINEER, technical graduate, age 32, married, desires position with light and power company or construction company. Ten years' experience, factory, central station, substation, construction, maintenance, operation four years, G. E. Company test, construction engineering. To demonstrate ability will consider most anything promising advancement. Available immediately. B-8366.

RECENT GRADUATE, B. S. in E. E., age 24. Two years' testing experience with the General Electric Company and a large Light and Power Company. Desires a position with a Light and Power Company in the construction, operating or distribution department. B-8370.

ELECTRICAL GRADUATE, 17 months G. E. test and switchboard engineering. Desires opportunity on construction or maintainance. Student member A. I. E. E. B-8365.

ELECTRICAL ENGINEER, a Virginia Tech. graduate desires work in the Electrical field. One year's experience at East Pittsburgh Plant of Westinghouse. B-8367.

ELECTRICAL ENGINEER, interested in connection with automatic hydroelectic power development and investigation. Five years' experience in power plant design and estimating work including two years testing course with

large electrical manufacturer. Associate A. I. E. E., University graduate. B-8368.

CHIEF ELECTRICIAN, ten years' experience in all kinds of wiring, repair, general jobbing, maintenance, also expert locksmith, wishes position offering advancement, preferably along engineering lines. Graduate Electrical Engineering American School, Associate member A. I. E. E. Age 34, married. B-8369.

RECENT GRADUATE, B. S. in E. E., desires position in testing department of an electrical manufacturing firm or power plant. Testing experience limited to that obtained at college. Location preferably New York. B-8265.

PUBLIC UTILITY EXECUTIVE, electrical and mechanical engineer, broad experience construction, operation, organization, management, financing, and consolidation Electric and Gas properties; excellent financing connections. B-8020.

YOUNG MAN, 24, E. E. graduate 1924, five years' experience machine drawing and checking, also inspecting, desires similar or research work with an electrical concern in New York City. Available on one week's notice. B-7270.

GRADUATE ELECTRICAL ENGINEER, capable of handling all phases of distribution engineering work wishes to affiliate with progressive power company. Have also had valuable experience in design of power plants and substations. Have excellent references and would be available on reasonable notice. B-7585.

GRADUATE ELECTRICAL ENGINEER, age 33, desires position with a public utility or industrial firm offering opportunities for advancement. Test experience with Westinghouse Electric Company. Commercial and distribution experience with Power Company. Experience in layout and construction of power plants and substations. Also experience in operation of gas plant and distribution system. Salary asked $2400. B-8379.

M. I. T. GRADUATE, S. B. in Electro-chemical Engineering, June 1922, and S. M. (no course but specializing in Electrical Engineering, Physics and Mathematics) June 1924. Some teaching experience as commissioned officer in the army at a college during the World War. Desires teaching position (instructorship, or assistantship in Physics, Electrical Engineering, Chemistry or Mathematics) for 1924-1925, at an Eastern College or Technical School, with opportunity for further study. B-8380.

ELECTRICAL ENGINEER, B. S. degree, University of Wisconsin, 1913. Experience as follows: three years with state utility commission in valuation, inspection and statistical departments. Two years successful operation of combined gas, electric and heating plant. Six years commercial engineering investigations and utility appraisal reports. Location desired dependent upon opportunity offered. B-8373.

TEN YEARS' EXPERIENCE in manufacturing; process improvement and cost reduction. Electro-chemistry at Boston Tech, followed by thorough shop course, gives the basis for success in manufacturing or research. Also fitted for personnel or rate setting work, and for instructor in the mechanical arts. Married, in best of health, American. B-3549.

ELECTRICAL ENGINEER, 35, desires position in industrial field. Nine years with the General Electric Company; also has had four years consulting engineering and contracting experience and two years engineering in the coal mining industry. Qualified to lay out hoist, pump and fan installations also the application of electric mining locomotives. Married. B-5674.

GRADUATE ELECTRICAL ENGINEER, age 26. Desires position with company offering opportunity for future advancement. Four years' experience in maintenance of textile plants, experienced in power plant operation and maintenance, chief operating engineer's license, present position master mechanic of textile mill. B-7928.

GRADUATE MECHANICAL - ELECTRICAL ENGINEER, twenty years' experience. Desires connection with power or industrial company or with engineering firm. Six years installation work and later District Engineer large electrical manufacturer. Wide experience industrial applications. Three years power department large paper manufacturer. Familiar operation and maintenance steam electric stations and boiler houses. B-6764.

GRADUATE ELECTRICAL ENGINEER, 31, desires to make satisfactory connections with engineering firm, consulting engineer, or investment bankers employing engineers. Seven years design and research engineering experience in connection with power plants, substations, and distribution system of largest electrical traction system in the country. B-7846.

TEACHER-ELECTRICAL ENGINEER, temporarily associated with a large utility company wishes to consider a professorship in a progressive educational institution. Teaching experience of many years covers all basic and many specialized electrical engineering courses, both theory and laboratory. Broad experience in the industry with both manufacturing and utility companies. Salary about $3500. Available September first. B-7083.

M. I. T. GRADUATE, 1922, E. E., now working at sales promotion and power service installation in large public utility would like position in sales, commercial or business work where technical training would be of use. B-6509.

RECENT GRADUATE, B. S. in E. E., 25, married. Six months' experience in house and industrial illumination. Four months' experience as steel mill electrician and motor inspector. One and one half years salesmanship. Soon finishing Alexander Hamilton Institute course. Desires position in engineering sales work over small area. Great Lakes states preferred. B-8393.

ELECTRICAL ENGINEER with E. E. degree. Seven years' experience with electrical public utility covering operation, station and overhead engineering and power sales work. Some editorial work. Graduate in law and licensed. Wants position with utility, preferably a smaller utility in central states. Age 28, single; salary $225. B-8396.

MECHANICAL AND ELECTRICAL ENGINEER open for a position with power company, railroad, or other utility. Age 37, married. Fifteen years' experience in the design, construction, valuation and operation of power plants, steam and electric railways. Employed as an electrical engineer at the present time by the Westinghouse Electric & Mfg. Co., and will require fifteen days' notice to change. Salary minimum $3600. B-8398.

YOUNG ELECTRICAL ENGINEER, age 25, fifteen months' engineering and commercial experience desires position with public utility company. Willing to work hard and learn your methods. Wants something permanent and with a future. University graduate, speaks two foreign languages, American. B-7028.

1919 GRADUATE ELECTRICAL ENGINEER, graduate General Electric Test followed by switchboard and power transmission installation and maintenance. Two years' experience in radio research laboratory of well known electrical manufacturer, designing and testing. B-7724.

DEVELOPMENT ENGINEER, technical graduate, Mem. A. I. E. E. Thirteen years investigation, design and manufacture, six years installation, five years sales. Experienced in telegraph, telephone, radio and sound ranging apparatus and construction, submarine cable testing and laying, cable machinery, submarine boats, automobiles and trucks. Age 47, married, excellent health. B-5948.

ELECTRICAL ENGINEERING GRADUATE, M. I. T., married. Have designed and installed low head hydro-electric plants and distribution systems. Two years Am. Tel. and Tel. Co. Recently chief engineer of steam railroad. Wants permanent connection with public utility or industrial offering good opportunities. Prefer New England or New York. B-8387.

GRADUATE ELECTRICAL ENGINEER, has had two years of sales and technical experience, willing worker and ready to apply himself. Wishes to connect with a reliable concern, is open to radio firms also. New York City and vicinity preferred. B-7227.

ENGINEER-EXECUTIVE, fifteen years' practical experience in sales and industrial engineering with central station and Westinghouse Electric & Manufacturing Co. Manager of electrical contracting department; general manager of electrical jobbing supply company. Technical university graduate. Location preferred, eastern or southern U. S. B-6619.

ENGINEER-EXECUTIVE, technical graduate, good engineering and business experience, practical mechanic, desires position of responsibility with public utility, manufacturer or railroad. B-3598.

EXECUTIVE of proven ability, with a clean record of twenty years in public utilities, from General Electric Company Test to General Manager public utility. Experience covers the construction of and operation of street railway, power, both hydraulic and steam, gas and general management. References of the best. Now engaged in consulting engineering in New York City. B-2215.

ELECTRICAL ENGINEER, technical graduate, age 31, desires connection with an industrial plant or central station company. Ten years' experience with a large central station company along technical lines. Also four years' teaching experience in E. E. in evening schools. Best references can be furnished. B-6530.

INSTRUCTOR in electricity and affiliated subjects. B. S. in Electrical Engineering, age 26, American, Associate A. I. E. E. Four years' experience, including two years industrial electrical construction and operation, one year electrical drafting and design, and one year electrical testing with public utility. Available on sixty days' notice. Will contract for two years' service on $2400 basis. B-8151.

ELECTRICAL ENGINEER experienced in sales; having held positions as sales engineer and sales manager. Would consider offer from reputable firm on salary and commission basis at first; commission only after few months. Able to manage, direct and guide salesmen, as well as direct sales by himself. B-6668.

ELECTRICAL ENGINEER, fourteen years' experience with prominent consulting engineers in responsible positions on design, construction, operation and valuation of electric, gas and railway properties. Now employed. Desire permanent location. Age 36, married, Member A. I. E. E., Member A. S. M. E. B-8410.

TECHNICAL GRADUATE with B. S. E. E. degree, age 34, married. Five years' experience, desires permanent connection with an industrial plant or contracting company in electrical construction maintenance or research departments. B-8352.

ELECTRICAL ENGINEER, graduate M. I. T. with post graduate study and research in electrical engineering. Two years' experience testing electric machinery, desires sales position where knowledge of electrical engineering is necessary. B-8414.

ELECTRICAL ENGINEER, 28, single; Spanish born. Five years' experience in power plant operating, laboratory work and selling power plant equipment. At present employed in distribution and installation department of large electrical utility company. Minimum salary $65 to start. B-8425.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

APPLICATIONS FOR ELECTION

Application have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1924.

Aikens, A. J., The Pacific Tel. & Tel. Co., Sacramento, Calif.
Anderson, F. L., Anderson Improvement Co., St. Paul, Minn.
Bailey, H. R., Portland Electric Power Co., Portland, Ore.
Baud, R. V., 160 E. 56th St., New York, N. Y.
Benson, H. E.,The Pacific Tel. & Tel. Co., Sacramento, Calif.
Bisaillion, W. A., Canadian Car & Foundry Co., Montreal, Que., Can.
Blackwell, E. S., Stone & Webster, Inc., Seattle, Wash.
Bucher, F. J., Public Service Co. of Northern Illinois, Chicago, Ill.
Cannizzaro, A., General Electric Co., Pittsfield, Mass.
Collins, E. J., Philadelphia Electric Co., Philadelphia, Pa.
Conrad, W. D., The Pacific Tel. & Tel. Co., Sacramento, Calif.
Davolio, U., Thompson-Starrett Co., New York, N. Y.
De Lellis, J., 630 Morris Ave., New York, N. Y.
Dinapoli, D. P., Pacific Gas & Electric Co., San Francisco, Calif.
Dunleavy, B. J., American Insulating Machinery Co., Philadelphia, Pa.
Ferguson, R., University of Illinois, Urbana, Ill.
Fitchett, W. Otis, General Electric Co., Bloomfield, N. J.
Fry, M., The Pacific Tel. & Tel. Co., Sacramento, Calif.
Gable, M., Westinghouse Elec. & Mfg. Co., Richmond, Va.
Garth, R. M., West Penn Power Co., Pittsburgh, Pa.
Geyer, F. H., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Gooding, C. C., The Pacific Tel. & Tel. Co., Sacramento, Calif.
Grunstein, W., Columbia University, New York, N. Y.
Hill, F. W. L., (Member), Electric Bond & Share Co., New York, N. Y.
(Application for re-election.)
Hitchcock, C. H., Western Electric Co., Inc., Hawthorne Sta., Chicago, Ill.
Hitchcock, W. J., 82 W. Filmore Ave., Corona, N. Y.
Johnson, G. C., Northwestern Bell Tel. Co., Fargo, N. Dak.
Kline, F. W., Northern States Power Co., Minneapolis, Minn.
Lacy, T. N., (Member), American Tel. & Tel. Co., Atlanta, Ga.
Lewis, H. C., Coyne Electrical School, Chicago, Ill.
Lowe, L. E., U. S. Cast Iron Pipe Foundry Co., Chattanooga, Tenn.
Mahn, H., Hendrie & Bolthoff Mfg. & Supply Co., Denver, Colo.
Napper, R. E., General Electric Co., New York, N. Y.
Palmer, W. G., The Ohio Bell Telephone Co., Toledo, Ohio
Patterson, L. L., (Member), A. & M. College, A. & M. College, Miss.
Perkins, L. M., (Member) Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ramsay, D. M., Jr., General Electric Co., West Lynn, Mass.
Randall, L., Hartford Electric Light Co., Hartford, Conn.
Reeves, C. V., Edison Elec. Illuminating Co. of Boston, Boston, Mass.
Rosenthal, H., (Member) L. L. Summers & Co., New York, N. Y.
Russell, E. E., The Pacific Tel. & Tel. Co., Sacramento, Calif.
Scheuermann, O., Russell & Stoll Co., New York, N. Y.
Scholz, W. P., I. R. T. Co., New York, N. Y.
(Application for re-election.)
Shaffer, F. J., The Ohio Public Service Co., Mansfield, Ohio
Smith, A. V., The Counties Gas & Electric Co., Norristown, Pa.
Squire, H. H., Jr., Hawthorne Works, Western Elec. Co., Chicago, Ill.
Stembel, D. M., Union Gas & Electric Co., Cincinnati, Ohio
Stover, P. A., Iowa Electric Co., Cedar Rapids, Iowa
Taranik, J. S., Pacific Gas & Elec. Co., San Francisco, Calif.
Thomas, W. C., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Toth, J., Jr., Contractor, Fairfield, Conn.
Turner, R. E., Pennsylvania Water & Power Co., Holtwood, Pa.
Uhl, J. F., National Carbon Co., Inc., Chicago, Ill.
Wagner, M. A., Pinellas County Power Co., St. Petersburg, Fla.
Warner, S. F., Western Electric Co., Inc., Hawthorne Sta., Chicago, Ill.
Watts, T. S., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Whittlesey, W. A., (Member), Pittsfield Electric Co., Pittsfield, Mass.
(Application for re-election.)
Winstanley, P. H., Siemens Brothers & Co., Ltd., Winnipeg, Man., Can.
Wood, O. L., Jr., General Electric Co., Schenectady, N. Y.
Youngs, C. L., Board of Water & Elec. Lt. Commisioners, Lansing, Mich.
Total 60.

Foreign

Ferguson, J. D., (Member) Ministry of Posts & Telegraphs, Dublin Castle, Irish Free State
Irvine, H. B., Survey Dept., Christchurch, N. Z.
Merchant, T. B., College of Technology, Manchester, Eng.
Samuel, R. A. P., Compagnie du Chemin de fer Paris-Orleans, Paris, France
Singh, B. M., (Member) Public Works Dept., Raisina, Delhi Prov., India
Total 5.

OFFICERS OF A. I. E. E. 1924-1925

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Farley Osgood

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Frank B. Jewett

Vice-Presidents
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Herbert S. Sands
S. E. M. Henderson
H. E. Bussey
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Honorary Secretary
Ralph W. Pope

LOCAL HONORARY SECRETARIES

T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina
Carroll M. Mauseau, Caixa Postal No. 571, Rio de Janeiro, Brazil
Charles le Maistre, 28 Victoria St., London, S. W., England
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France
H. P. Gibbs, Tata Sons, Ltd., Navsari Building, Fort Bombay, India
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy
Eiji Aoyagi, Kyoto Imperial University, Kyoto, Japan
Lawrence Birks, Public Works Department, Wellington, New Zealand
Axel F. Enstrom, 24 A Grefturegatan, Stockholm, Sweden
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa

A. I. E. E. COMMITTEES

The list of committees is omitted from this issue, as new appointments are being made for the administrative year commencing August 1. The new committees will be listed in the September issue.

A. I. E. E. REPRESENTATION

A complete list of A. I. E. E. representatives on various bodies will be published in the September issue.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	P. C. Jones	C. D. Black, B. F. Goodrich Co., Akron, Ohio
Atlanta	W. R. Collier	H. N. Pye, Box 1743, Atlanta, Ga.
Baltimore	W. B. Kouwenhoven	R. T. Greer, Lexington Building, Baltimore, Md.
Boston	F. S. Dellenbaugh	W. H. Colburn, 39 Boylston St., Boston, Mass.
Chicago	G. H. Jones	K. A. Auty, Room 1000, Edison Bldg., Chicago, Ill.
Cincinnati	O. Shepard	Ernest Fields, West End Sta., Union Gas & Electric Co., Cincinnati, O.
Cleveland	C. P. Cooper	R. A. Carle, City Water Department, Cleveland, O.
Columbus	F. R. Price	O. A. Robins, 1517 Franklin Ave., Columbus, O.
Connecticut	Wm. A. Moore	A. E. Knowlton, Dunham Laboratory, Yale University, New Haven, Conn.
Denver	W. C. Du Vall	R. B. Bonney, Telephone Building, Denver, Colo.
Detroit-Ann Arbor	F. L. Snyder	G. B. McCabe, Detroit Edison Co., Detroit, Mich.
Erie	B. L. Delack	L. H. Curtis, General Electric Co., Erie, Pa.
Fort Wayne	C. C. Grandy	L. C. Yapp, General Electric Co., Ft. Wayne, Ind.
Indianapolis-Lafayette	W. A. Black	Victor T. Mavity, 539 N. Capitol Ave., Indianapolis, Ind
Ithaca	J. G. Pertsch, Jr.	Geo. F. Bason, Cornell University, Ithaca, N. Y.
Kansas City	D. D. Clarke	G. E. Meredith, Kansas City Pr. & Lt. Co., Kansas City, Mo.
Lehigh Valley	J. L. Beaver	G. W. Brooks, Penna. Power & Light Co., Allentown, Pa.
Los Angeles	E. R. Stauffacher	O. F. Johnson, 740 S. Olive St., Los Angeles, Calif.
Lynn	B. W. St. Clair	H. S. Twisden, General Electric Co., Lynn, Mass.
Madison	R. G. Walter	Leo J. Peters, Elec. Laboratory, University of Wisconsin, Madison, Wis.
Mexico	D. K. Lewis	E. F. Lopez, Fresno No. 111, Mexico, D. F., Mexico
Milwaukee	C. T. Evans	F. K. Brainard, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Minnesota	E. H. Scofield	Allen Dewars, St. Paul Gas & Electric Co., St. Paul, Minn.
New York	H. H. Barnes, Jr.	R. H. Tapscott, 124 E. 15th St., New York, N. Y.
Oklahoma	T. M. Fariss	A. D. Stoddard, Box 382, Bartlesville, Okla.
Panama	F. B. Coyle	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	C. D. Fawcett	R. H. Silbert, Philadelphia Elec. Co., 2301 Market St., Philadelphia, Pa.
Pittsburgh	M. E. Skinner	G. S. Humphrey, West Penn Power Co., 14 Wood St., Pittsburgh, Pa.
Pittsfield	N. F. Hanley	J. R. Rue, General Electric Co., Pittsfield, Mass.
Portland, Ore.	E. F. Pearson	H. P. Cramer, Portland Electric, Power Co., Electric Bldg. Portland, Ore.
Providence	W. B. Lewis	F. N. Tompkins, Brown University, Providence, R. I.
Rochester	F. T. Byrne	E. A. Reinke, Stromberg-Carlson Tel. Mfg. Co., Rochester, N. Y.
St. Louis	B. D. Hull	Cris H. Kraft, 315 N. 12th St., St. Louis, Mo.
San Francisco	F. R. George	A. G. Jones, 807 Rialto Building, San Francisco, Calif.
Schenectady	R. C. Muir	C. M. Cogan, Lighting Engg. Dept., General Electric Co., Schenectady, N. Y.
Seattle	J. Hellenthal	C. E. Mong, 505 Telephone Bldg., Seattle, Wash.
Southern Virginia	Wm. C. Bell	Harold C. Leonard, P. O. Box 1194, Richmond, Va.
Spokane	J. S. McNair	Joseph Wimmer, Home Tel. & Tel. Co., 165 S. Howard St., Spokane, Wash.
Springfield, Mass.	J. M. Newton	J. Frank Murray, United Elec. Lt. Co., Springfield, Mass.
Syracuse	W. C. Pearce	L. N. Street, College of Applied Science, Syracuse University, Syracuse, N. Y.
Toledo	Gilbert Southern	Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	H. C. Don Carlos	W. L. Amos, Hydro Elec. Power Commission, 190 University Ave., Toronto, Ont.
Urbana	Chas. T. Knipp	Charles A. Keener, 308 Electrical Laboratory, University of Illinois, Urbana, Ill.
Utah	H. W. Clark	John Salberg, W. E. & M. Co., Walker Bank Bldg., Salt Lake City, Utah
Vancouver	C. N. Beebe	A. Vilstrup, B. C. Electric Railway Co., 425 Carroll St., Vancouver, B. C.
Washington, D. C.	J. H. Ferry	Frank R. Mueller, Bliss Electrical School, Washington, D. C.
Worcester	S. M. Anson	Fred B. Crosby, 15 Belmont St., Worcester, Mass.
Total 47		

LIST OF BRANCHES

Name and Location	Chairman	Secretary
Alabama Poly Inst., Auburn, Ala.	R. C. Dickerson	L. R. Housel
Alabama, Univ. of, University, Ala.	L. L. Evans	C. M. Lang
Arizona, Univ. of, Tucson, Ariz.	Roy Osborne	Edward Moyle
Arkansas, Univ. of, Fayetteville, Ark.	Hugh McCain	R. T. Purdy
Armour Inst. of Tech., Chicago, Ill.	D. E. Richardson	J. S. Farrell
Brooklyn Poly Inst., Brooklyn, N. Y.	H. B. Hanstein	J. H. Loerch
Bucknell Univ., Lewisburg, Pa.	E. S. Hopler	A. L. Huffman
California Inst. of Tech., Pasadena	R. O. Elmore	M. L. Beeson
California, Univ. of, Berkeley, Calif.	F. C. Blocksom	M. Nutting
Carnegie Inst. of Tech., Pittsburgh, Pa.	P. M. Hissom	D. Beecher
Case School of Applied Science, Cleveland, O.	H. P. Davis	George Geyser
Catholic Univ. of America, Washington, D. C.	C. G. Kirby	J. W. Dolan
Cincinnati, Univ. of, Cincinnati, O.	Ray Coughton	W. C. Osterbrook
Clarkson Coll. of Tech., Potsdam, N.Y.	L. L. Merrill	E. T. Augustine
Clemson Agri. College, Clemson College, S. C.	R. W. Pugh	O. A. Roberts
Colorado State Agri. Coll., Ft. Collins	Frank Ayres	Lyndall Hands
Colorado, Univ. of, Boulder, Colo.	G. Cartwright	W. T. Crossman
Cooper Union, New York	E. J. Kennedy	A. W. Carlson
Denver, Univ. of, Denver, Colo.	C. G. Diller	Ray Hoover
Drexel Institute, Philadelphia, Pa.	H. Shelley	D. L. Michelson
Florida, Univ. of, Gainesville, Fla.	J. R. Benton	Geo. Harrison
Georgia School of Tech., Atlanta, Ga.	R. A. Goodburn	J. A. Minor
Iowa State College, Ames, Iowa	V. Womeldorf	G. G. Thomas
Iowa, Univ. of, Iowa City, Iowa	G. C. K. Johnson	C. A. Von Hoene
Kansas State College, Manhattan	V. O. Clements	W. K. Lockhart
Kansas, Univ. of, Lawrence, Kans.	C. H. Freese	G. R. Vernon
Kentucky, Univ. of, Lexington, Ky.	K. R. Smith	J D. Taggart
Lafayette College, Easton, Pa.	Wm. Welsh	J. B. Powell
Lehigh Univ., S. Bethlehem, Pa.	E. W. Baker	D. C. Luce
Lewis Institute, Chicago, Ill.	E Millison	C. P Meek
Maine, Univ. of, Orono, Me.	H. L. Kelley	H. E. Bragg
Marquette Univ., Milwaukee, Wis.	W. J. Hebard	C. Legler
Massachusetts Inst. of Tech., Cambridge, Mass.	G. P. Davis	F. J. Hecht, Jr.
Michigan Agri. Coll., East Lansing	C. M. Park	O. Dausman
Michigan, Univ. of, Ann Arbor, Mich.	F. J. Goellner	M. H. Lloyd
Milwaukee, Engg. School of, Milwaukee, Wis.	I. L. Illing	A. U. Stearns
Minnesota, Univ. of, Minneapolis	R. W. Kellar	H. R. Reed
Missouri, Univ. of, Columbia, Mo.	M. P. Weinbach	
Montana State Coll., Bozeman, Mont.	Jack Cowan	J. A. Thaler
Nebraska, Univ. of, Lincoln, Neb.	H. Edgerton	O. A. Andrews
Nevada, Univ. of, Reno, Nev.	Robert Plaus	G. Fowble
North Carolina State College, Raleigh, N. C.	A. C. Bangs	J. C. Richert, Jr.
North Carolina, Univ. of, Chapel Hill	T. B. Smiley	H. L. Coe
North Dakota, Univ. of, University	S. J. Nogosek	T. E. Lee
Northeastern Univ., Boston, Mass.	L. F. Hubby	E. G. Crockett
Notre Dame, Univ. of, Notre Dame, Ind.	Frank Egan	K. Faiver
Ohio Northern Univ., Ada, Ohio	Mr. Cotner	J. K. Fulks
Ohio State Univ., Columbus, O.	T. A. McCann	R. E. Madden
Oklahoma A. & M. Coll., Stillwater	F. C. Todd	R. W. Twidwell
Oklahoma, Univ. of, Norman, Okla.	R B Greene	M F Hill
Oregon Agri. Coll., Corvallis, Ore	M P. Bailey	E. E. Bricker
Pennsylvania State College, State College, Pa.	C. MacGuffie	J. H. Schmidt
Pennsylvania, Univ. of, Philadelphia	G. V. Cresson	O. Ortlieb
Pittsburgh, Univ. of, Pittsburgh, Pa.	G. H. Campbell	F. Wills
Purdue Univ., Lafayette, Ind.	S. B. Mills	M. G. Seim
Rensselaer Poly. Inst., Troy, N. Y.	F. M. Sebast	B. R. Chamberlain
Rhode Island State Coll. Kingston, R.I.	C. S. North	D. Brown
Rose Poly. Inst., Terre Haute, Ind.	P. Wilkens	R. A. Reddie
Rutgers College, New Brunswick, N. J.	E. G. Riley	E. J. Butler
South Dakota, Univ. of, Vermillion, S. D.	E. N. Clarke	S. M. Lawton
Southern California, Univ. of, Los Angeles, Calif.	H. A. McCarter	Chet Little
Stanford Univ., Stanford University, Calif.	M. L. Wiedmann	A. C. Wright
Swarthmore Coll., Swarthmore, Pa.	A. L. Williams	S. R. Keare
Syracuse Univ., Syracuse, N. Y.	E. J. Agnew	J. G. Hummel
Tennessee, Univ. of, Knoxville, Tenn.	S. R. Woods	W. T. Elliott
Texas A. & M. Coll., College Station	A. A. Ward	L. H. Cardwell
Texas, Univ. of, Austin, Tex.	G. C. Hengy	W. K. Sonnemann
Utah, Univ. of, Salt Lake City, Utah	I. J. Kaar	M. B. McCullough
Virginia Military Inst., Lexington	J. M. Yates	J. B. Lacy, Jr.
Virginia Poly. Inst., Blacksburg, Va.	F. L. McClung	E. M. Melton
Virginia, Univ. of, University, Va.	T. S. Martin, Jr.	J. W. McNair
Washington, State Coll. of, Pullman	J. Dunkin	J. T. Yasumura
Washington Univ., St. Louis, Mo.	H. Spoehrer	C. M. Dunn
Washington, Univ. of, Seattle, Wash.	John Weir	J. W. Lewis
West Virginia Univ., Morgantown	O. A. Brown	James Copley
Wisconsin, Univ. of, Madison, Wis.	H. G. Holmes	K. E. Wooldridge
Yale Univ., New Haven, Conn.	W. C. Downing, Jr.	O. B. Skinner
Total 77		

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Starterless Motor.—Bulletin 133, 36 pp. Describes the "Pow-R-full" starterless motor. Wagner Electric Corporation, St. Louis, Mo.

Brushes and Carbon Products.—Catalog, loose-leaf, describing the complete line of carbon products of the National Carbon Company, Cleveland, Ohio.

Instrument Transformers.—Bulletin 65, 28 pp., describing "Sangamo" instrument transformers. Sangamo Electric Company, Springfield, Illinois.

Planer Motors.—Bulletin 2016, 24 pp., describing type heavy "T" duty planer motors for reversing service. The Reliance Electric & Engineering Company, Ivanhoe Road, Cleveland, Ohio.

D. C. Switchboard Instruments.—Bulletin 430, 12 pp. Describes ammeters, voltmeters, volt-ammeters, shunts and multipliers. Roller-Smith Company, 12 Park Place, New York.

Condenser Tubes.—A reprint of a paper (24 pp.) presented before the A. S. M. E. by Wm. R. Webster, describes manufacture and practice. Bridgeport Brass Company, Bridgeport, Conn.

Remote Control Switches.—A manual, 64 pages, describing multi-circuit switches, no voltage release switches, tank switches, relays and solenoid devices. The Hart Manufacturing Company, Hartford, Conn.

Motors.—New price book and data sheets covering direct-current, polyphase motors up to 75 h. p. An original method of arranging the dimension sketches enables these to be quickly read. Star Electric Motor Company, Miller Street & New Jersey R. R. Avenue, Newark, N. J.

Motor Drives in Ice Plants.—A reprint of a paper (16 pp.) on "Synchronous Motor Drives in Ice and Refrigerating Plants" by Truman Hibbard, presented at the Fourth International Congress of Refrigeration, London, June 1924. Electric Machinery Manufacturing Company, Minneapolis, Minn.

Fire Brick Bonding Material.—Bulletin, 20 pp., "Hytempite in the Power Plant." Illustrates and describes some of the applications of "Hytempite," in refractory construction and maintenance. Quigley Furnace Specialties Company, Inc., 26 Cortlandt Street, New York.

Protective Device for Small Motors.—Bulletin 103, 12 pp. Describes the "Minibreaker" a miniature circuit breaker, for small a-c. and d-c. motors. Miniature Breaker Company, Inc., 200 Fourteenth Street, Long Island City, N. Y.

Street Lighting.—Booklet, 36 pp., "The Splendor of Well Lighted Streets." Outlines the resources of the G-E. Company at the service of the public for the lighting of its cities. The booklet contains contributions by the late Charles P. Steinmetz, Thomas A. Edison, Elihu Thomson and W. D'A. Ryan. An attractive cover painted in colors by Walter L. Greene, binds the booklet. General Electric Company, Schenectady, N. Y.

Graphic Meters.—Bulletin 624, 4 pp. Describes a line of graphic meters having an arrangement by which the chart speed is increased at the start of a line disturbance. The chart operates at 3 inches per hour under normal conditions, but as soon as a disturbance occurs the speed increases to 3 inches per minute, thus insuring a detailed record of conditions in times of disturbances, and of value in analyzing causes. Four kinds of instruments are equipped with this feature—ammeters, voltmeters, wattmeters and power-factor meters. The Esterline-Angus Company, Indianapolis, Ind.

Grounding Devices.—Bulletin, "Groundits and Groundology," 16 pp. Contains articles on metal conduit and pipe as conductors, and the common ground conductor, together with other heretofore unpublished data on the electrical characteristics of metal raceways and copper ground wires, and the choking effect of metal conduit on a single conductor carrying 60 cycle current. The various types of grounding fittings manufactured by the Groundulet Company are described. "Groundology."—Bulletin, G2, 12 pp. is a detailed analysis of the subject of protective grounding of a-c. services, including quotations of all requirements of the National Electrical Safety Code and miscellaneous other codes and authorities. The Groundulet Company, 86 Park Place, Newark, N. J.

NOTES OF THE INDUSTRY

Western Electric Sales Increase.—Charles G. DuBois, President of the Western Electric Company, just before sailing for Europe the latter part of June, stated that the sales of the Company for the first five months of this year have been the largest on record, totalling $122,280,000, as compared with $93,478,406 for the corresponding period of 1923.

The Triumph Electric Company, Cincinnati, Ohio, announces the appointment of R. W. Hobart in charge of motor sales, and the appointment of R. C. Hayes as sales manager for the Triumph Ice Machine Company Division, E. C. Morse, vice-president in charge of sales having resigned.

The W. C. Fletcher Company, Fletcher Trust Building, Indianapolis, Indiana, has been appointed representative to handle motor sales in the southern half of Indiana.

New Station for New York Edison Company.—A new power station with an ultimate capacity of 700,000 kw., is to be constructed by the New York Edison Company, it is announced by the General Electric Company, with whom the order for the first two turbine-generators has been placed. These turbine generators have a rated capacity of 60,000-kw. at unity power factor, 25 cycles, 11,400 volts, three-phase, to run at 1500 revolutions per minute. These machines will operate at 350 lb. steam pressure, 700 degrees Fahrenheit maximum temperature. They will be equipped with direct connected exciters and will exceed by 10,000 kilowatts capacity the present largest single unit machines now operating. The machines are scheduled for delivery during the Spring of 1926.

Electric Drive for New Steamship.—Contracts for the construction of the largest electrically propelled sea-going passenger liner have recently been given the Cramp Shipbuilding Company by the American-Hawaiian Steamship Company, Inc. The turbine-electric propulsion equipment, consisting of two Curtis turbines with a total of 20,000 horse power will be supplied from water tube boilers burning oil. The turbines will drive two alternating current generators of 7700 kw. each, which in turn will drive two G-E synchronous motors of 10,000 horsepower, direct connected to the propeller shafts. The completed vessel will cost about $5,000,000 and will operate between San Francisco and Honolulu. Accommodations will be provided for 600 first class passengers and 250 members of the crew.

The Norma Company of America now the Norma-Hoffmann Bearings Corporation.—In order better to describe the nature of its business, The Norma Company of America, Long Island City, N. Y. has changed its name to the Norma-Hoffmann Bearings Corporation, with the same management, personnel and policies as heretofore. The "Norma" precision ball bearing was introduced in America some twelve years ago. About two years ago the Norma Company acquired the American rights in patents, trade marks and business of the Hoffmann Manufacturing Company, Ltd., of Chelmsford, England, makers of roller bearings. To provide for the constantly growing demand for "Norma" precision ball bearings and to permit the manufacture of "Hoffmann" precision roller bearings and "Hoffmann" steel rollers, the company has just completed a new and modern plant on its seventeen acres of property at Stamford, Conn., on the main line of the N. Y., N. H. & H. R. R.